IoT and AI-based Water Quality Monitor and Neutralizer

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***Abstract*—Managing the quality of water is important for the sustainability of the environment, considering conditions of rivers, ponds, swimming pools, or fish tanks in which the water has a quality below the set standards. This is detrimental for aquatic organisms and even humans. This paper describes a novel IoT Water Neutraliser Pod, an IoT based device which is aimed at continuously monitoring and neutralising water by using smart sensors and automated modalities of treatment. The pod includes pH, turbidity and TDS sensors for real time quality assessment of water. The sensor data is collected and stored on a Firebase Realtime Database which allows monitoring through a custom developed Android application and website. Users can visualize water quality and determine if the water is fit for consumption or needs treatment. The system can autonomously dispense neutralizing agents to the water sensor to water ratio, making the water optimal to drink. This solution is viable for commercial social applications and for example, swimming pools and aquariums. This system helps to maintain water quality and real time monitoring, cloud storage, and automated neutralization of water for optimal conditions. An efficient and scalable approach to water quality management is provided through this system with minimal supervision in diverse settings.**

***Index Terms*—Autonomous Water Monitoring, Raspberry Pi, Microcontrollers, Remote, Cloud, Real-time Water Analysis, Floating Sensor Platform, Chemical Dosing System, PCB (Printed Circuit Board), Circuit Design, Power Management, Wireless Communication**

water treatment is labor intensive and requires samples to be pulled which is not efficient and requires a lot of time.

In this paper, a Water Neutralizer pod is discussed that aims at tackling these challenges by incorporating IoT technology, real time water assessment, and automatic neutralization of the water. The pod checks the quality of the water by measuring pH, temperature, and TDS by scanning the water quality parameters continuously. The data that has been collected is then sent to a Firebase Realtime Database. A visualization of this data is done using an Android application which serves as an interface where the user can monitor the state of the water, if it is treated or in need of treatment. The system can also ensure that the water stays within a safe limit by automatically charging neutralizing agents to combat the negative effects.

Such a strategy is particularly useful for use in business, like for all types of swimming pools or substantial water bodies, where proper conditioning of water is needed. It is also important for social purposes, like private aquariums, where the water must be suitable life for organisms. The system ensures efficient provision and sustains water quality in the respective environments while IoT and cloud-based monitoring, as well as automated treatment, reduces manual effort.

I. INTRODUCTION

Maintaining access to water that is clean and safe has grown to be quite a challenge, specifically in health areas that are urbanized and even in rural land when pollutants and the pH level of the water is not balanced. Water quality in rivers, ponds, and even in swimming pools can be used, poor quality water can result in health challenges, algae blooms, and even destruction of underwater ecosystems. Likewise, In tanks for fish and even in smaller water bodies, the optimum level of pH, turbidity, and even dissolved solids has to be maintained if aquatic forms of life are to thrive. Manual as well as traditional

II. LITERATURE REVIEW

A. Current Trends and Research Gaps

Rivers and various other water bodies have a great impact on the daily water requirement for human consumption. Kumar and Goyal studied and explored the impact of river pollution [1]. Additionally, they did a detailed study on the regulatory and remedial paths to overcome these challenges. Therefore, Minde in the article explored various cost-effective and sus- tainable ways to manage wastewater [2]. Rapid urbanization had affected water bodies. But, the paper explored robust and novel approach for the waste water management.

Various approaches were taken into considerations to mon- itor the water quality. In the paper by Jayaraman, detailed research was done on the appraoches using machine learning and IoT [3]. It used various parameter such as turbidity, tds, pH and temperature to monitor water quality. This achieved a compelling accuracy comparing to the existing approaches. In addition, the paper also used the geospatial information. Beltran in the paper studies a technique to monitor water quality using artifical intelligence [4].

Similarly, Varsha also researched IoT based smart water quality monitoring system [5]. Water bodies getting contam- inated challenges the consumption needs. On the other hand, Yogesh and the team used the raspberry pi to monitor and conserve water in the tank [6]. Although, it was limited to water quality monitoring. Therefore, by understanding the challenges in these research papers, we identified the gap. The existing studies were limited to montoring or neutralization with human intervention. Our study included water quality monitoring and neutralization autonomously with the use of AI and IoT.

III. RESEARCH QUESTIONS

RQ1: In what ways can the efficiency of chemical treatment in natural water bodies be enhanced by monitoring water quality in real-time?

RQ2: In what way can sensor technology be applied in order to make water quality monitoring more affordable for rural and underdeveloped areas?

RQ3: How can artificial intelligence be utilized to anticipate shifts in water quality with the help of a floating sensor system?

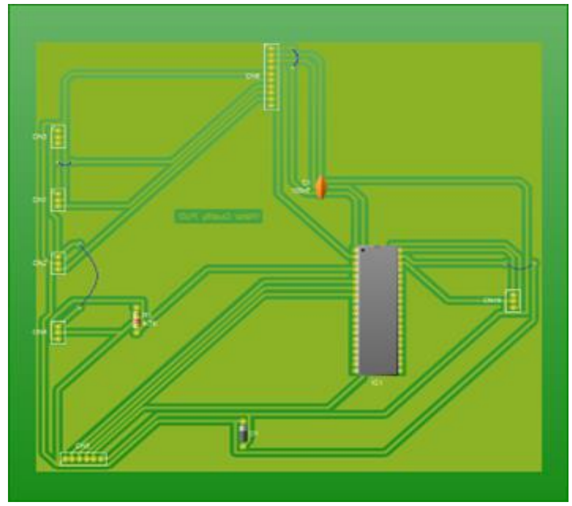

Fig. 1. PCB layout

(grounding and insertion detection). Then the power pin is passed through a 5A fuse to connect with LM2956-S (DC-DC Buck Converter). Here, the fuse protects the buck converter in the case of fluctuations. As the battery powers 11.4V, we need 5V to power the raspberry Pi and 3.3V to power other auxiliary components such as sensors and ADC. The first buck converter converts 11.4V into 5V which is then followed by another buck converter to convert 5V to 3.3 V. These have fuses in between them to overcome the risk of current fluctuation. In the end, there is a pinout which further connects with the main board. The pin out consists of 5V, 3.3V and ground pins.

IV. SYSTEM DESIGN AND METHODOLOGY

A. System Design

In this paper, we have presented a model on autonomous water quality analyzer and neutralizer. The basic ideology behind this model is to demonstrate the removal of human intervention to neutralize the water bodies. In addition to this, it skips the time taken in the process of complex laboratory testing.

In the system architecture of our model, as in the figure, the model employs raspberry pi with the custom printed circuit board (PCB).

The PCB has been divided into two boards considering the electrical specifications and characteristics:

1) Power Board: As in the figure, the power board consists of the power management components that aim to power the main board without interfering with the electrical paths of other components. This board consists of a dc jack, 3 fuse (Two 5 A and One 1 A), Two DC-DC buck converter (for 5V and 3.3V) and three pin out (5V, 3.3V and Ground) to connect the main board. To power the board, we have used a 2500 mAH NMC Li-ion battery pack which must be able to DC power the main board for 3-4 hrs. This battery pack is connected to the power board via dc socket. The DC jack in the board has three pins which are power and ground

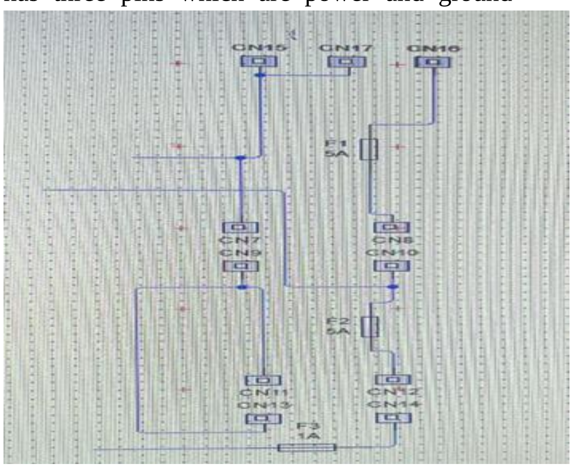

Fig. 2. Power PCB Schematic

2) Main Board: In the figure, the main board is illustrated which houses the Raspberry Pi 4b, Analog to digital converter, motor driver, sensors and passive components. Primarily, the main board is powered by the power board for 5V, 3.3V and Ground. This is directly done to the raspberry pi pin. This in return powers all the other components. These sensors which are TDS, turbidity, pH and temperature sensors have three pins which are power, ground and Data. The data pins from the ph sensor, tds sensor and turbidity sensors are connected to ADC (ADS1115) to get the analog data converted into digital data. This is then sent to raspberry pi via GPIO pins. The temperature sensor (DSB18B20) does not need ADC as it has digital data captured and sent directly to the raspberry pi.

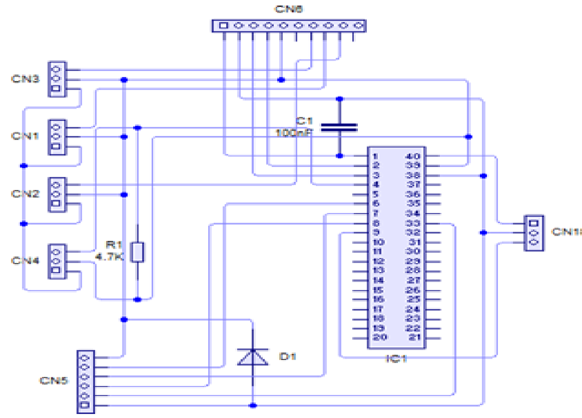

Fig. 3. Main PCB Schematic

Based on the input from the sensors and the parameter set, the prompts are sent to the motor driver for the activation of the motors. These motors on the activation release the necessary chemicals onto the water bodies to neutralize the constituents. Once the motor activates, it keeps running until the parameter has been reached to the certain threshold. Overall, the main board is the brain of the model which consists of all the components from sensors to the motors.

B. Hardware Components

Components	Purpose
Raspberry Pi 4B	Data Processing
Sensors: pH, TDS, Turbidity, DS18B20	Measures pH level, dissolved solids, turbidity, and temperature
Submersible Pump	Chemical Dosing
Battery (11,500 mAh, 11.4V)	Power Supply
Buck Converter	Step-down DC-DC converter
IoT (WiFi)	Communication
Fuse, Capacitors, Resistors, Diodes	Passive Components
Relay Module (4-channel)	Controls submersible pumps

C. Software Implementation

A Raspberry Pi module is used in the water neutralizer's POD project to collect real-time data on water quality, such as pH, turbidity, and real-time data on TDS, etc., and it is sent to the Firebase Realtime Database for storage. The Android app, created in Android Studio using Kotlin, collects this data from Firebase and presents it in an easy-toread text format, indicating whether the water is safe for aquatic life or drinkable. Through the graph and pie chart, the site—which was developed using React and Node.js—connects to the more

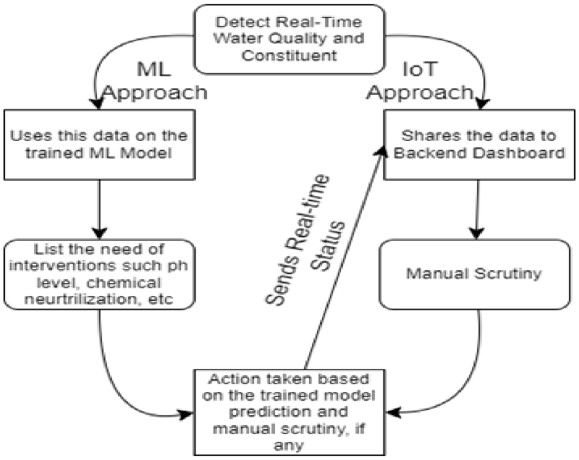

Fig. 4. System Flowchart

intensive visualization of the data collected, causing the user to check the pattern in water quality over time. It is also able to provide dynamic insight into the data on water quality; a chatbot has also been used on the site. Which uses the Gemini API and the Gemini 2.0 flash model to give dynamic data. By using the linked sensors to monitor continuous water parameters, Raspberry Pi Firebase processes raw data locally before sending the Firebase in real time without the need for a cloud function. The Raspberry Pi module itself handles the data processing algorithm and guarantees that only structured, relevant data will be sent to the cloud. Firebase's Cloud Recording Facility makes it easy to restore data from the site and the Android app, which will allow consumers to access the latest water quality data at any time.

V. RESULTS & DISCUSSION

After a detailed study and development of the project, we answer the RQ1, RQ2 and RQ3 based on the following results and discussion:

Real Time Water Quality Monitoring: The system enables monitoring and analysis of various parameters of water in one single device, i.e. pH, turbidity,tds, etc. This ensures continuous and timely detection of any water contamination. reduced labor cost

Compact System: By combining various ML techniques, the device is designed in such a way that it performs various tasks in one single device, unlike other devices where every param- eter is required as a separate device. This device solves the problem of using separate devices for each water parameter.

Improved Efficiency: By eliminating the use of separate devices, it reduces manpower, as it also treats water by dis- posing of water treatment chemicals (ferric chloride, calcium hydroxide) that are required to clean the water body. Resulting in peak efficiency due to the automation and data-driven approach.

Remote Access to Analytics through Web-app: As seen in the figure 6, 7 and 8, The user is in the control of all the operations since A web application is created to interface,

Fig. 5. Compact Model with Successfully Monitoring Water Quality through Sensors and Netralizing Water through Motors

monitor and take necessary actions remotely, this leads to advancement in the system making it reliable as well as efficient.

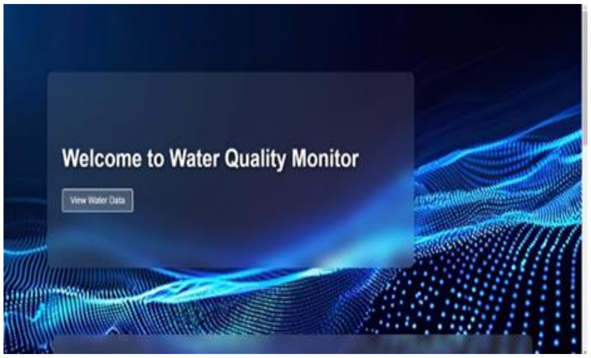

Fig. 6. Welcome page of Web-app

Fig. 7. Real-time Water Quality Monitoring

Autonomous Chemical Dispose: The motor pumps attached to the pod help to deploy chemicals from the container of the chemical. Each chemical is deployed according to the impurity that the water body specifically has, resulting in automaticity without any human intervention.

VI. CONCLUSION

The implementation of a water quality monitoring and purification system based on IoT and machine learning demon- strated significant advantages, including real-time analysis, reduced labor costs, and improved efficiency. By integrating multiple sensors and automated chemical dosing, the sys- tem ensures accurate water quality assessment and timely

Fig. 8. Real-time Water Quality Monitoring and Neutralization

intervention. The ability to remotely monitor and manage water parameters through a web or mobile interface enhances accessibility and decision-making. Although challenges such as connectivity issues and maintenance requirements were observed, the system proved to be a highly effective and efficient alternative to traditional water testing and treatment methods.

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