IoT-based Realtime Water Quality Management System using Arduino Microcontroller

K. Chandra Sekhar[1], Byna Venkatesh[2], Korchipati Sudeep Reddy[2], Guntimadugu Giridhar[2], Koppulu Nithin[2], Kinnera Eshwar[2]

[1]Assistant Professor, Dept. of ECE, Geethanjali Institute of Science and Technology, Nellore, Andhra Pradesh, India

[2]UG Student, Dept. of ECE, Geethanjali Institute of Science and Technology, Nellore, Andhra Pradesh, India

ABSTRACT

In the modern world, water pollution is a significant cause of various water-borne diseases, including dengue, cholera, and malaria, among others, affecting human beings. Approximately 40% of global deaths are attributed to water pollution. Therefore, it is crucial to continuously monitor the quality of drinking water during its distribution to consumers. This article proposes a cost-effective design and expansion of a real-time water quality measuring system using the Internet of Things (IoT). The system aims to measure physical and chemical parameters such as temperature, humidity, pH, and turbidity. Water contamination poses a significant threat to sustainable development. Continuous monitoring of water quality is essential to ensure the availability of safe drinking water. This paper presents the development and implementation of a simplified framework for real-time water quality monitoring using IoT. The system consists of multiple sensors capable of measuring various physical and chemical parameters of water, including temperature, pH, turbidity, and humidity. These sensor readings can be configured and monitored by a central controller, with the ATMEGA328 model serving as the core controller. The collected sensor data can be accessed online using a Wi-Fi network. The automation in the project is controlled by a microcontroller, which receives data transmitted from a PC over Wi-Fi through a Wi-Fi module. All components are interconnected with the Arduino microcontroller. The Arduino ATMEGA328 microcontroller processes the input and generates the necessary output using the ARDUINO IDE with Embedded C programming. The entire system is powered by a regulated power supply, providing a DC voltage of 5V to all hardware modules.

Keywords: Water quality management, Internet of things, Arduino controller, pH sensor, Turbidity sensor.

1. Introduction

Water plays a vital role in the creation of human beings and other natural phenomena. Approximately 80% of diseases in developing countries are caused by the consumption of polluted water. It is well-known that water is not only used for drinking purposes but also has various other uses such as in economic aspects, industrial sites, agriculture, fishing, and other constructive activities. The quality of water is primarily affected by physical, chemical, and biological factors. Lakes, rivers, glaciers, groundwater, and rainwater are among the main sources of water. Water is available in every part of the Earth, whether it is polluted or not, with around 80 percent of the planet's land covered by water. In our day-to-day lives, water plays a crucial role for all living beings on Earth. The quality of water has gained significant attention in our generation. Therefore, it is essential to check the water quality in order to live a healthy and prosperous life. In the past, water quality was measured by taking water samples, sending them to laboratories, and conducting examinations. However, this process is costly,

time-consuming, and requires extensive human resources. Furthermore, it does not provide real-time data and may lead to impure water quality.

The proposed water quality monitoring systems, which consist of a microcontroller and common sensors, are compact and highly useful for measuring the pH, turbidity, temperature, and humidity of water. They provide continuous and real-time data. In summary, the introduction of a water quality monitoring system is an essential step towards ensuring the safety and sustainability of water resources. It provides crucial information that can be used to manage and protect water quality, as well as to ensure responsible use of water resources. In the current era, we are striving to make our cities smart cities, thanks to the technological research and inventions that have taken place over the decades. This era is often referred to as the era of inventions, development, globalization, and smartness. However, there is a downside to this progress, which includes pollution, global warming, insecurity, and poor health factors. The main causes of these issues are the ignorance of people and the government sector, as well as the deficient water quality monitoring system, which results in serious health issues.

1.1 Problem definition

To develop a system that can continuously monitor and analyze the quality of water in real-time, providing accurate and timely data on various parameters such as pH, turbidity, temperature, and humidity. The system should be capable of detecting and alerting users about any deviations or anomalies in water quality, enabling proactive measures to be taken to address potential issues. Additionally, the system should be cost-effective, easy to deploy, and accessible to both individuals and organizations involved in water management, such as households, industries, and government bodies. The ultimate goal is to ensure the safety and sustainability of water resources by enabling efficient monitoring and management of water quality.

2. LITERATURE SURVEY

Pasika and Gandla (2022) [1] proposed a monitoring system which consists of a number of sensors usedto measure several quality parameters like turbidity, pH value, water level in the tank, dampness of the adjoining environment and temperature of the water. The sensors are interfaced with the Microcontroller Unit (MCU) and additional processing is executed by the Personal Computer (PC). The acquired data will be directed to the cloud by means of Internet of Things (IoT) based ThinkSpeak ap-aplication for monitoring the quality of the water under test. As a future directive, work should be extended for analyzing some other parameters such as nitrates, electrical conductivity, dissolved oxygen in the water and free residual chlorine. Mukta et al (2021) [2] developed an IoT based Smart Water Quality Monitoring (SWQM) system which helps in incessant measurement of quality of water on the basis of four different parameters of water quality i.e., pH, temperature, turbidity and electric conductivity. Four different sensors are coupledto Arduino Uno in order to sense the quality parameters. The data collected from all the four sensorsare communicated to a desktop application which is developed in .NET platform and the extracteddata are matched with the standard values. On the basis of the collected data from sensors, the developed SWQM model will efficaciously examine the water quality parameters by employing fast forest binary classifier for classification of the sample of water under test is whether potable ornot. Konde and Deosarkar (2021) [3] proposed a method for developing a Smart Water Quality Monitoring (SWQM) system with reconfigurable sensor interface device using IoT environment. Sensors, Field Programmable Gate Array (FPGA) board, Zigbee based wireless communication module were usedin the proposed model. Six different water quality parameters like turbidity, pH, humidity, water level, water temperature and carbon dioxide (CO2) on the surface of water were considered in real-time. The proposed method

will provide assistance in guarding the safer and balanced environmentof water bodies. The SWQM system reduces the cost and time in determining the quality of waterin water resources as part of managing environmental and ecological balance. In the suggested future work, WSN network will be developed involving of additional number of nodes to encompass the coverage area.

Amruta and Satish (2021) [4] proposed a Solar Powered Water Quality Monitoring system by employing wireless Sensor Network. Underwater Wireless Sensor Network (UWSN) is the elementary component in the water quality monitoring using wireless sensor network (WSN) technology whichis powered by photovoltaic panels or solar panels. For monitoring quality of water in real-time overvarious locations, exceptional system architecture is proposed that consists of a base station and distributed sensor nodes. All the nodes and base stations are linked with the use of Zigbee WSN technology. Designing and implementing a prototype model by using a node which is power- driven by solar panel and WSN technology is a perplexing task. The collected data at each node such as turbidity, oxygen level and pH values from different sensors will be sent to the base station throughWSN. The collected data from the different locations can be shown in some readable form and analysis can be done at base station using various simulation tools. This developed novel water quality monitoring system has various advantages like consumption of less power, no carbon emission and higher limberness. Sughapriya et al (2021) [5] developed a method for determining the quality of water using IoT and different sensor modules. This system uses different sensors for monitoring the water quality by determining pH, turbidity, conductivity and temperature. The Arduino controller used will access the sensor data. With the use of IoT, the collected data is analyzed, and the pollution of water can be investigated by a stringent mechanism. Additionally, the developed system sends alerts and notifications to the people and apprehensive authorities about the quality of water. The task of waterquality monitoring could be achieved by with people having less training also. Installation of the water quality monitoring system could be achieved effortlessly adjacent to the water resources (target area). The proposed developed model comprises of different sensors that compute qualityparameters of water in real- time for immediate plan of action. Also, the developed model is accurate, economical and requires less manpower. Unnikrishna Menon et al. (2022) [6] proposed a method for water quality monitoring in rivers which is developed based on wireless sensor networks that aid in incessant and remote monitoring of waterquality parameters. In this system, wireless sensor node is designed to monitor the pH of water continuously, which is the key parameter that affects the water quality. The sensor node design primarily consists of a processing module, signal conditioning module, power module and wirelesscommunication module. The sensed data from the pH sensor is communicated to the base station with the use wireless communication module i.e., using Zigbee module after the necessary signal processing and signal conditioning techniques. The circuit is developed for the sensor node by designing, simulating and the hardware prototype is built with the use of suitable circuit components. This minimizes requirement of power for the system and a low-cost platform is provided for monitoring the water quality of water resources.

Prasad et al. (2020) [7] developed a method for smart water quality monitoring system in Fiji, by employing remote sensing and IoT technology. The quality parameters used to analyze water are Oxidation and Reduction potential (ORP) and Potential Hydrogen (pH). With efficacious implementation of this approach of monitoring, an early warning system for water pollution will be developed with a completely implemented system using numerous monitoring stations. The study of water quality in Fiji Islands is also presented which necessitates recurrent data collection network for water quality monitoring using IoT and Remote Sensing. The comparative study is presented for various parameters like Turbidity, pH, temperature, and Conductivity. The developed system has

demonstrated its effectiveness by providing precise and reliable values in real-time water monitoring. Four water sources were examined at hourly intervals over a stipulated time interval of 12 hours to validate the accuracy of measurement of the developed system. The obtained results are compared with the probable values. The relationship between temperature withconductivity and pH are also witnessed for samples of all four water sources. GSM technology was efficaciously implemented for sending alarms on the basis of reference parameters to the end user for instant action intended for ensuring water quality. Furthermore, the reference parameters acquired from all the four various water sources are used for building classifiers that are used for performing automated analysis of water through Neural Network Analysis.

Jerom B. et al. (2019) [8] proposed a Smart Water Quality Monitoring System based on IoT using Cloudand Deep Learning methods for monitoring the water quality of various water resources. In traditional methods, the procedure of monitor ring involves collecting the sample of water manually from different water resources, trailed by testing and analysis in the laboratory. This process is usually ineffectual since this process is strenuous and consumes more time and it will not give results in realtime. There should be continuous monitoring of quality of water for ensuringsafe supply of water to the end users from any water resources or water bodies. Henceforth, designing and developing a cost-effective system for real-time monitoring water quality using the IoT is a requisite. Monitoring quality of water in water resources using IoT aids for combating issues related to environment and improves the wellbeing and standard of living of all living beings.The developed system helps in monitoring the water quality persistently by using IoT devices andNode-MCU. The built-in Wi-Fi module associated with Node-MCU facilitates connectivity of internet, and transmits the data measured from the sensor to the Cloud. The designed prototype monitors a number of contaminants present in the water. Various sensors are utilized for measuringdifferent parameters for assessing the water quality from water resources. The obtained results arestowed in the Cloud and deep learning techniques are employed for predicting if the water under test is potable or not.

Geetha and Gouthami(2019)[9] developed a low powered and naiver solution for monitoring quality ofin-pipe water based on IoT. The developed model is used to test samples of water and the data collected from the sensors is uploaded over the internet is analyzed. This model is less complex and low cost smart water quality monitoring system with a core controller having built-in Wi-Fi module for monitoring quality parameters like turbidity, conductivity and pH. The developed system comprises of an alerting facility for informing the users on deviance of water quality parameters. The implementation facilitates sensors to provide data over the internet to the end customers. The setup used for the experiment can be enhanced by integrating algorithms for incongruity detection in quality of water.

Sengupta et al. (20218) [9] proposed a cost-effective technique for monitoring water quality and controlling in real-time using IoT. The proposed system comprises of different sensors like temperature sensor, turbidity sensor and pH sensor that are interfaced with Raspberry Pi via an Analog-to-Digital Converter (ADC). Based on the data obtained from various sensors and processing of data by the Raspberry Pi, the solenoid valve will be directed to either continue or stopthe flow of water from the overhead tank to houses using relay mechanism. This entire process takes place automatically without human intervention thus saving the time to handle the situation manually. Finally, its checks for weather water quality parameters are desired range or not. These all devices are low cost, flexible and high efficiency. Kumar and Samalla (2018) [10] proposed a cost-effective system to monitor quality of water in real-timeusing IoT. The designed system used various sensors to measure the chemical and physical parameters of the water. This smart water quality system consists of a Raspberry pi controller interfaced with various sensors like CO2 sensor, pH

sensor, turbidity sensors, temperature sensor and water level sensors. These sensors control the entire operation and monitoring is done by Cloudbased wireless communication devices.

3. EXISTING SYSTEM

There are several Existing systems for water quality monitoring that are used different parts in the world. Laboratory-Based Water Quality Testing: This involves collecting water samples and analyzing them in a laboratory for a range of parameters such as chemical composition, microbiological contamination, and toxicity. In the existing system the pH Value and temperature we can measure at certain limit range. But in the proposed system we can integrate the system with IOT to find temperature, turbidity, pH value, Humidity to monitor the conditions Drinking water faces many challenges in the current situation due to growing population and pollutants from industries, agriculture waste etc., are mixed with drinking water. Traditional methods to test drinking water quality parameters like turbidity, pH, conductivity and temperature etc., may consume time because samples are tested manually in the laboratory. Also, there has been coding in Raspberry Pi. Raspberry units working with normal coding also created so much slow operation of the unit. Overall, the choice of water quality monitoring system depends on the specific needs and resources of the organization or agency responsible for monitoring water quality. A combination of differentmethods may be used to provide a comprehensive picture of water quality over time and across different locations.

4. PROPOSED SYSTEM

The whole design of the system is based mainly on IOT which is a newly introduced concept in the world of development. There are basically two parts included, the first one is hardware & second one is software. The hardware part has sensors which help to measure the real time values, another one is Arduino atmega328 converts the analog values to digital one, & LCD shows the displays output from sensors, Wi-Fi module gives the connection between hardware and software. In software we developed a program based on embedded c language. The PCB is designed at the first level of construction and component and sensors mounted on it. An app is installed in the android version to see the output. When the system gets started the 230v alternating current is converted into 5v dc which is given to the kit and Arduino and WIFI get on. The parameters of water are tested one by one, and their result is given to the LCD display. The app went provided with hotspot gives the exact value as on LCD display shows on kit. Thus, like this when the kit is located on any specific water body and WIFI is provided we can observe its real time value on our android phone anywhere at any time.

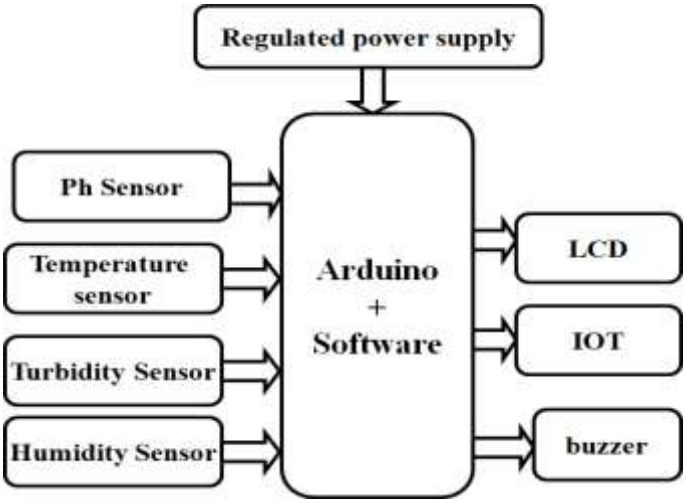

Figure 1: Proposed block diagram of water quality monitoring system.

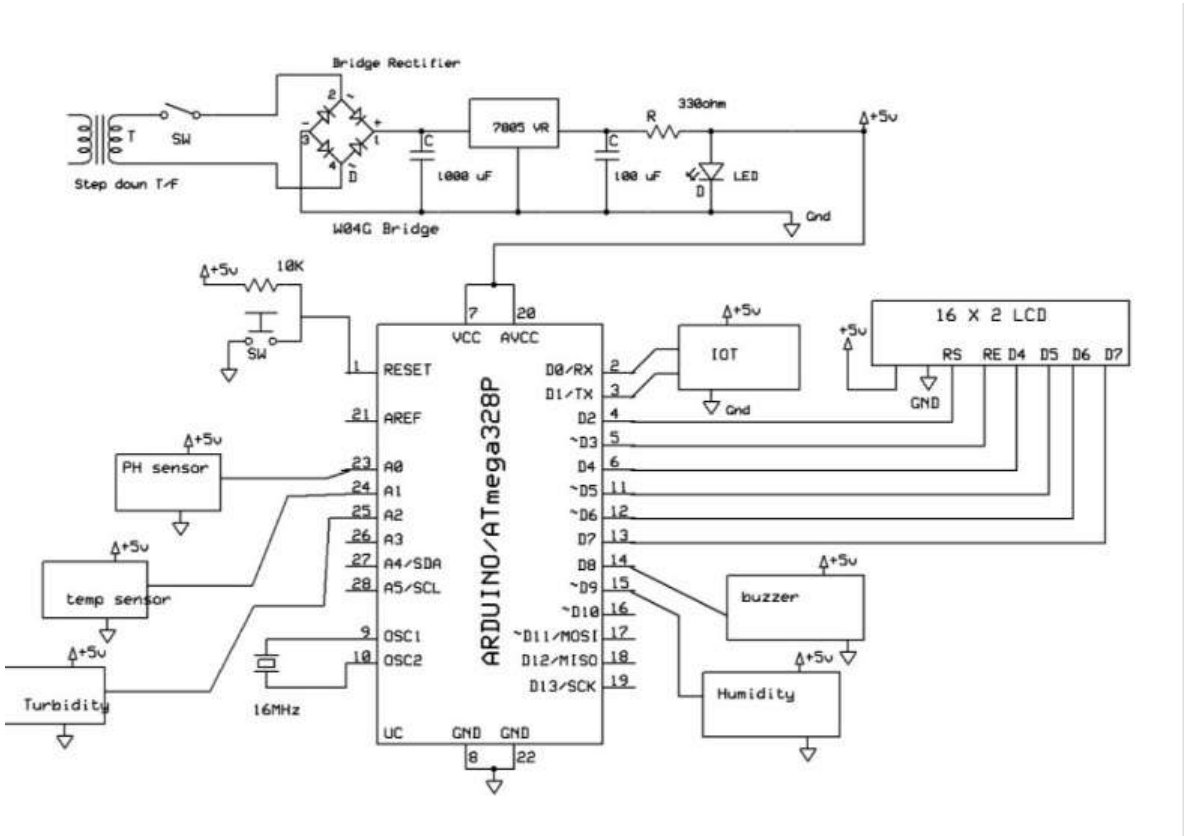

Figure 2: Schematic diagram of proposed system.

4.1 Sensor's description

pH Sensor: pH sensors are electronic devices used to measure the acidity or alkalinity of a liquid, including water. They work based on the principle of detecting the concentration of hydrogen ions in the solution. pH sensors typically consist of a glass electrode that generates a voltage proportional to the pH level, and a reference electrode that provides a stable reference voltage. The output from the sensor is usually in the form of a voltage signal that can be interpreted and converted into a pH value using appropriate calibration.

Turbidity Sensor: Turbidity sensors are designed to measure the cloudiness or turbidity of a liquid, which is an indicator of the presence of suspended particles in the water. These sensors use a light source and a photodetector to measure the amount of light scattered or absorbed by the particles in the water. The sensor provides an output signal that is proportional to the turbidity level, typically in terms of Nephelometric Turbidity Units (NTU) or Formazin Turbidity Units (FTU).

Temperature Sensor: Temperature sensors are widely used to measure the temperature of water and other substances. Various types of temperature sensors exist, including thermocouples, resistance temperature detectors (RTDs), and thermistors. Thermocouples generate a voltage proportional to the temperature difference between two junctions, while RTDs and thermistors rely on changes in electrical resistance with temperature. Temperature sensors provide accurate temperature readings that can be used for monitoring and controlling water temperature in different applications.

Humidity Sensor: Humidity sensors, also known as hygrometers, are devices used to measure the amount of moisture or water vapor present in the air or other gases. These sensors detect changes in humidity by measuring changes in capacitance, resistance, or thermal conductivity of a moisture-absorbing material. Capacitive humidity sensors are commonly used, and work based on the principle

that the capacitance of a moisture-sensitive material changes with humidity. Humidity sensors provide information about the relative humidity, which is expressed as a percentage.

These sensors, when integrated into an IoT-based real-time water quality management system using Arduino, enable continuous monitoring of crucial parameters. The collected data from these sensors can be transmitted wirelessly to a central server for analysis, allowing for proactive decision-making and timely interventions to maintain water quality within acceptable ranges.

4.2 IoT module

The ESP8266 IoT module is a popular and versatile Wi-Fi enabled microcontroller board designed for Internet of Things (IoT) applications. It is widely used due to its low cost, small form factor, and integrated Wi-Fi capabilities. The ESP8266 module is based on the ESP8266 chip, which contains a microcontroller unit (MCU) along with a built-in Wi-Fi module.

Key features of the ESP8266 IoT module include:

Microcontroller: The module is equipped with a powerful 32-bit Tensilica Xtensa LX106 microcontroller with a clock speed of 80 MHz. It provides sufficient processing power and memory for running IoT applications.

Wi-Fi Connectivity: The built-in Wi-Fi module allows the ESP8266 module to connect to wireless networks, making it ideal for IoT applications that require remote monitoring and control. It supports both Station (STA) mode for connecting to an existing Wi-Fi network and Access Point (AP) mode for creating its own Wi-Fi network.

GPIO Pins: The module features a number of general-purpose input/output (GPIO) pins that can be used for interfacing with various sensors, actuators, and other electronic components. These pins can be programmed to support digital input/output, analog input, PWM output, and other functionalities.

Programming: The ESP8266 module can be programmed using the Arduino IDE (Integrated Development Environment) with the help of additional libraries specifically designed for ESP8266. It also supports programming with MicroPython, Lua, and other programming languages.

Integrated TCP/IP Stack: The module includes an integrated TCP/IP stack, allowing it to communicate over the internet using protocols such as HTTP, MQTT, TCP, UDP, etc. This enables seamless integration with cloud platforms and remote servers for data exchange.

Low Power Consumption: The ESP8266 module is designed to operate efficiently in terms of power consumption, making it suitable for battery-powered or low-power IoT applications.

SDK and Development Resources: The ESP8266 ecosystem provides an extensive software development kit (SDK) and a wealth of community support. This facilitates rapid development of IoT applications and offers a wide range of resources, tutorials, and sample codes.

4.3 Buzzer Functioning

A piezoelectric buzzer is a type of sound-producing device that utilizes the piezoelectric effect to generate sound waves. In water quality management, piezoelectric buzzers can be employed as an audible alert system to indicate certain conditions or events related to water quality. Here's how a piezoelectric buzzer works:

Piezoelectric Material: The buzzer consists of a piezoelectric element, usually made of a ceramic material such as lead zirconate titanate (PZT). Piezoelectric materials exhibit a unique property - they can generate an electric charge when subjected to mechanical stress or vibration.

Oscillation Circuit: The buzzer is typically connected to an oscillation circuit, which provides an alternating current (AC) signal at a specific frequency. When the AC signal is applied to the piezoelectric element, it causes the material to vibrate mechanically.

Sound Generation: The mechanical vibrations of the piezoelectric element, in turn, generate sound waves in the surrounding medium, typically air. These sound waves propagate as audible sound, creating the buzzing or beeping noise associated with the buzzer.

In the context of water quality management, piezoelectric buzzers can be used in conjunction with water quality monitoring systems or devices. They can serve as audible indicators to alert users when certain water quality parameters exceed or fall below predefined thresholds. For example, if the pH level of the water deviates from the acceptable range, the monitoring system can trigger the piezoelectric buzzer to emit a specific sound pattern or frequency. This audible alert can help prompt immediate attention to the water quality issue, allowing for timely corrective actions to be taken. Piezoelectric buzzers are preferred in water quality management applications due to their compact size, simplicity, and low power requirements. They can be easily integrated into monitoring systems, providing a cost-effective and reliable method for notifying users about critical water quality events.

5. Results and Discussion

Here the circuit is turned ON by giving the regulated power supply of 12v which is then converted to 5v dc current. The LED is the indication for 5v current so, if there is 5v current then automatically the LED glows. The generated 5v dc current passes to every hardware component in the circuit.

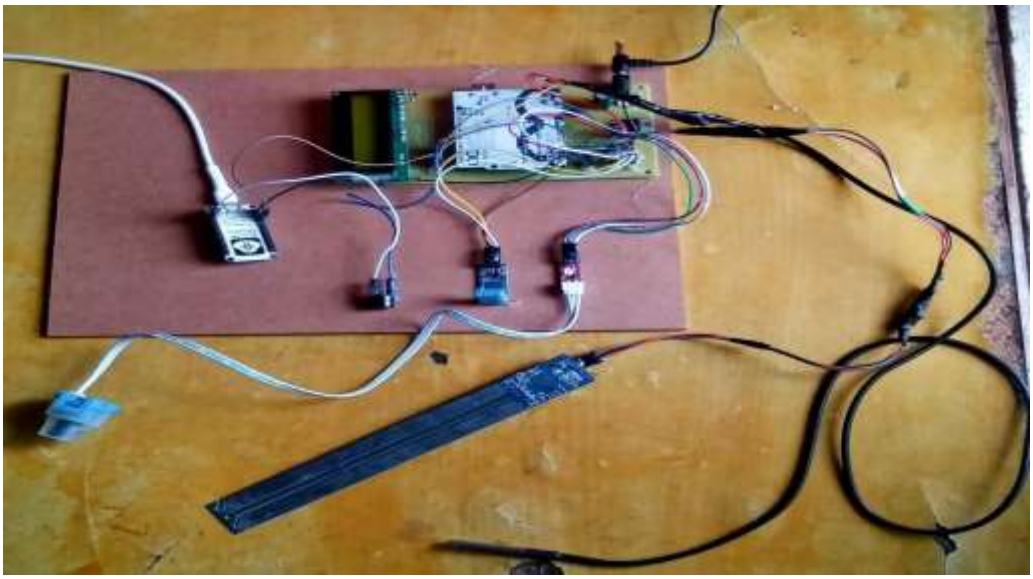

Figure 3. Overview of the designed kit.

Whenever the power supply is given to the circuit, the previously recorded values will be displayed on the LCD screen. After placing the sensors in the water, the display will show the values measured by the Real-time sensors accurately. The resultant values are displayed on the IoT Application. The values displayed on the IoT application are similar to the values displayed on the LCD display. It displays the PH and Turbidity and Temperature and Humidity Values.

Figure 4. Display values in LCD

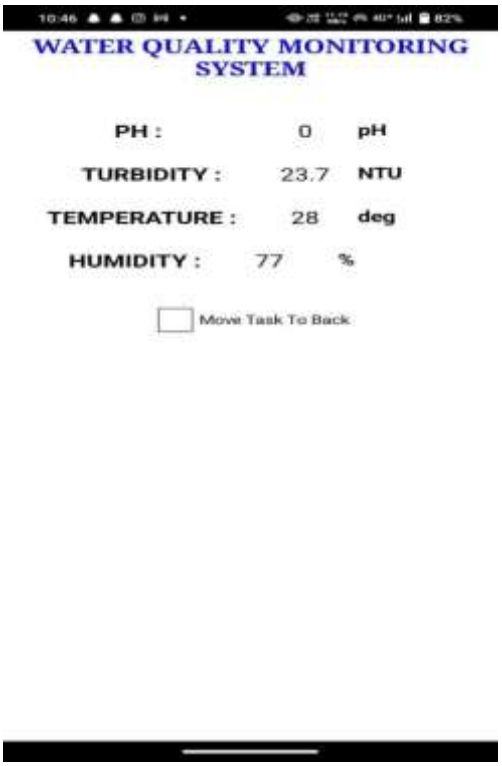

Figure 5. Values displayed in IOT application.

6. CONCLUSION

Water quality monitoring using IoT is a promising technology that can help ensure the safety and sustainability of water resources. The advantages of IoT-based water quality monitoring systems include continuous monitoring, cost-effectiveness, easy installation, and efficient data management. As the demand for water resources increases, it is important to adopt innovative technologies such as IoT-based water quality monitoring systems to ensure the safety and sustainability of our water resources. The future of water quality does not look better as the development and industrialization of the developing countries have just begun. Although, if the precautions are applied soon and the systems placed at the right time then it can be prevented well in developing countries. If the designs explored in the paper were to be implemented in the future then the need for human intervention

would be minimal and there will be more chances of getting good quality water in developing countries.

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