



IOT-ENABLED MONITORING SYSTEM FOR REAL-TIME ANALYSIS OF TURBIDITY, PH, AND TEMPERATURE IN WATER QUALITY

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Abstract: Water quality monitoring is a key factor in guaranteeing that freshwater resources are clean and sustainable. Developing in the past methods of testing parameters, like turbidity, pH, and temperature, is done by collecting samples manually and sending them to the laboratory for analysis. Certainly this approach doesn't match the requirements of more modern water quality monitoring. In order to accomplish this, we developed an advanced monitoring technique that allows the systems to detect turbidity, pH and temperature levels in water sources in a self-controlling way. The system is made up of sensors such as turbidity meter, pH meter, level sensor and temperature sensor, along with a single chip microcontroller data acquisition module, information transmission module, monitoring center and other accessories. A single-chip microcontroller is guiding the process of continuous viewing of water parameters and their real-time analyzing. Data picked up by the sensor systems are processed and transmitted to a command node, which, in turn, can activate an alert to the public through an IoT infrastructure. Due to increased global water consumption and water contamination concerns, the deployment of the IoT technologies for water quality inspection can be a suitable solution to guarantee water quality and safety.

Index Terms - IoT (Internet of Things), pH, Sensor technology, Temperature, Turbidity, Water quality monitoring

I. INTRODUCTION

Water quality is subject to change depending on its source and the treatment measures. Traditional testing techniques, which rely on manual sampling and laboratory analyses for factors such as turbidity, pH, and temperature, could go obsolete with the changing nature of the monitoring process. The implementation of an all-inclusive monitoring system is the outcome of which the evaluated factors of Turbidity, pH, water level, and Temperature, alongside a single-chip microcontroller data acquisition module, transmission module, and monitoring center, have been taken into account. This system brings the automated, continuous monitoring of the water quality parameters at their best with the one-chip micro controller doing the work of analyzing the data, whether for analysis or interpretation. In addition, it enables real-time alerts because of its innovative IoT infrastructure, thus creating public awareness and taking instant actions for water quality problems.

Water, one of the most essential natural resources essential for mankind survival and abundant enough to cover about 70% of the Earth summing up to approximately 326 million trillion gallons. Although fresh water, representing 97% of all water on the globe, is abundant, still it is among the most unavailable resources because it mainly exists as glaciers in non-accessible areas. Such restricted accessibility, barely 0.04% of the total, the Earth's water, presents huge challenges for sustainability in water consumption. Classification of fresh water into two streams – ground water in the form of canals, rivers and tanks, and surface water persuade the increasing pollution levels in the environment through discharge of waste and chemicals during production activities. One of the main imperatives is to strive for maintaining water quality

and availability, and thus consumers' health by the increasing globalization. Water supply and pollution control strategic management has been found worldwide as a critical issue, what could help to reconsider the activities in monitoring of water quality measures. These parameters span three main categories: physically related factors include saltness, turbidity, temperature, and water colour; chemical variables are the pH, dissolved oxygen, and heavy metal content; and microorganism markers comprise bacteria and coli forms (bacteria).

The conventional way of examining water quality was based on manual sample collection and is an ineffective and labor-intensive approach. On the edge of these advices, water quality monitoring researchers are more and more using the IoT unit for recording of water quality parameters, representing a novel and emerging technique in this area.

IoT is a kind of interconnected devices and systems that collects physical objects, data, human involvement and services in a networked environment. Since all these devices and other IoT components are battery-powered, they need to be connected to the network as well to guarantee the best functionality of the network.

The subsequent structure of the article unfolds as follows: Section two delves into a comprehensive literature review, Section three focuses on problem identification, and Section four elaborates on smart water quality monitoring systems. The fifth section unveils the results and initiates a discussion, while Section 6 encapsulates the article's conclusion.

II. RELATED WORKS

The examination of integrating fog/edge computing into IoT arises from its potential to enhance service delivery for end-users. By deploying computing services at the network edge, it offers resilience and improves user experience even in the event of failures. The decentralized nature of edge/fog computing, combined with its proximity to users, promises significant advancements in the timeliness and quality of IoT services. Consequently, the future infrastructure of IoT development is expected to heavily rely on fog/edge computer-based systems. Establishing a fog/edge computing-based IoT architecture requires a thorough investigation of architecture, enabling techniques, and related issues, followed by a discussion on integrating fog/edge computing with IoT [1].

The concept of the Internet of Things (IoT) encompasses a realm where countless objects, often referred to as "things," connect to the Internet, exchanging data autonomously and making decisions independently, without human intervention. As these IoT-connected objects evolve, they tend to become increasingly intelligent, contributing to the overall smartness of their environment. Middleware, a pivotal component of IoT software, plays a crucial role by furnishing the bulk of intelligence in IoT systems. It facilitates the integration of data from various devices, enabling communication and informed decision-making based on collected data. In this context, our discussion revolves around assessing the requirements of IoT middleware, elucidating its architecture reference model, and proposing advanced operational techniques for its modules to ensure optimal performance. Additionally, we address key security features vital for such software. Furthermore, we explore the trade-offs inherent in adopting and enforcing a widely accepted standard for IoT middleware. In essence, middleware emerges as an indispensable tool in the development of IoT solutions, serving as a reference model for architectural frameworks in this domain [2].

IoT is a communication interface between devices, cars and other common objects linked by embedded program software, sensors and connection, so that this system can generate and share data. The creations of IoT devices have been drastic, manifesting a consistent 31% year-over-year growth since 2017. It is predicted that until 2020 the number will increase incredibly by 30 billion.

In India, the improper disposal of municipal and industrial waste poses a significant environmental challenge, particularly in water pollution. Sewage discharge, particularly untreated, remains a major contributor to water contamination. Additionally, unregulated small-scale factories and agricultural practices contribute to the release of contaminants into water bodies.

The paper describes an up-to-date IoT-based Smart Water Pollution Monitoring System which employs cloud technology and deep learning algorithms to measure ecological state over various water bodies. Instead of the labor-intensive and time-consuming activity of manual sampling followed by laboratory analysis, the system offers a streamlined solution which solves the problem in real-time for monitoring water quality.

Drawbacks: The procedure proves inefficient due to its multistep nature, consuming considerable time and failing to yield real-time outcomes. Continuous monitoring of water standards is imperative to ensure its quality remains consistent across various water bodies and sources accessible to people [3].

The recent surge of interest in the Internet of Things (IoT) stems from its ability to seamlessly integrate into complex frameworks, owing to its expansive scope and numerous benefits. Sensing technologies

increase with radio-frequency identification evolution and thus IoT is at the edge of monitoring tools. This article focuses on an appraisal and general plan for the integration of IoT in structural health monitoring (SHM) which aims at productivity and conformity with established regulations. It explores feasible integration methods between IoT and SHM technologies and describes optimal choices for IoT ecosystems in terms of data routing. Given the unprecedented production capacity and speed of sensors, an influx of data necessitates the development of big data solutions to effectively manage the vast and intricate datasets generated by structural sensors [4].

With the emergence of IoT technology, healthcare services are now delivered in a personalized way, reaching all sectors including home health monitoring and remote patient care. IoT technology empowers healthcare service providers to serve the clients right in the comfort or from a distance. IoT shows a great ability to generate abundant data which is efficiently transferred and stored through cloud-based systems. Therefore, currently high latency of the cloud computing-based factual timely remote health monitoring is unacceptable due to exhibited data transmission delays. Hence, a more effective approach involving remote patient health monitoring through smart homes and fog computing at gateways has been proposed, therefore, the pattern in health care has come to change. The proposed model relies on data mining, distributed storage, and notification with the use of inbuilt data mining algorithms and computational intelligence. For the transmission of the real-time patient information with a fog-level processing, an event-driven data transfer scheme is employed. One of the most important benefits that data visualization presents is that it shows the proposed BBN classifier model which overcomes the rest of the classifications with precision and rate of execution being fast. In addition, the proposed system is empowered through improved access of real-time processing of healthcare data [5].

Advancing healthcare costs and the demand of home-based treatment showcases the urgent demand for reform in healthcare systems. Hence, major amounts of money have been put on projects that equip healthcare providers with the essential tools for remote health patient monitoring and evaluation. On the other hand, a lot of existing solutions do not have required adaptability, scalability, and energy efficiency. This article presents the state of the art: PPHM system that is a conjunction of IoT and Cloud computing technology that actually avail healthcare management remotely. The case study of such PPHM infrastructure viability will be presented through the real-time ECG monitoring of a congestive heart failure patient. Statistical analysis of the PPHM infrastructure confirms its power, scalability, and energy efficiency in carrying out remote patient health monitoring [6].

The relentless pursuit of developing smart applications has propelled IoT to unprecedented heights. In recent years, the industry has introduced IoT services and production and management systems aimed at boosting productivity. Wind energy has emerged as the most viable renewable energy source, particularly for electricity generation, albeit its encroachment on other services due to space constraints. The research herein discusses conducting a research that involves fabrication of a smart device whose function is the fast detection of defects in electric generators within wind turbines so as to optimize maintenance scheduling. With the help of four methods comprising of extracting features through vibration signal classification, supported by different classification algorithms based on neural networks, we accomplished 94.44% accuracy, a rate that is considered the highest recorded earlier. This is expressed though the percent of false positivity and negativity that is only 0.4% and 1.84% respectively [7].

III. PROBLEM STATEMENT

1. Traditional water testing methods are slow and inefficient, prompting the need for automated monitoring systems.
2. With water scarcity and pollution on the rise, real-time monitoring of key parameters like turbidity, pH, and temperature is essential.
3. The proposed system employs IoT technology to streamline data collection and ensure prompt action when water quality issues arise.

IV. PROPOSED SYSTEM

In this proposed system, we have developed a holistic technique for the continuous surveillance of the water quality parameters. The system relies on several water quality monitoring sensors such as pH, turbidity and temperature sensors which are smartly placed at the expected locations so as to get real-time data on the key water quality indicators.

Data is collected by sensors and is wirelessly forwarded to a microcontroller that can be viewed as a computer brain of this system. The microcontroller handles, processes, and analyzes the data coming from sensors, in fact guaranteeing the good quality of the data at the same time. Following processing, the

collected data are issued to a remote core controller via Zigbee format according to IEEE 802.15.4 network standard, which ensures a simple communication between the sensor devices and the central processing unit.

In order to boost the functionality and accessibility of this system, an IoT module is embedded which enables data transmission from the core controller to the cloud infrastructure. This integration is obtained by using the TCP/IP protocol which allows for efficient data transfer over the internet. Once the data has been uploaded into the cloud, it will be available to users all over the world.

On the other hand, the system includes an online browser-based program that roles out water quality parameters whenever the user wants, using a special IP address. The user-friendly and intuitive interface of the system helps the users to visualize and analyze collected field data; the users may then use the data to improve how they address water quality management.

Fig.1. below indicates the proposed water quality monitoring system, showing the networking of different parts that are responsible for data acquisition, processing, and remote monitoring. This systems framework brings together different technologies in one package to achieve continuous and dependable monitoring of water quality parameters. All the needed components for the water quality monitoring system are described in Table 1.

To build a portable water quality monitoring system capable of operation in a wireless network at remote locations for a long time, measures taken include low power consumption, affordability, and high detection precision. The proposed system, based on WSN technology, is segmented into five components:

4.1 Data Monitoring Nodes

The sensor accepts signals and this makes it to pass through some changes by signal conditioning circuit. Finally, the data is transmitted to the controller, which is the RF module of the transmitter. The data is directed towards the database station.

- Sensors like pH, turbidity, and temperature are deployed at the remote location to measure water quality parameters.
- The raw sensor data is first passed through a signal conditioning circuit to ensure accuracy and stability.
- The conditioned data is then sent to a microcontroller for processing.
- After processing, the data is transmitted wirelessly using RF modules to a central data collection point or database station.

4.2 Data Base Station

The data from all IoT nodes is captured and compiled at the database station, which is equipped with the ARM processor. This will be the next step in the process, since the data is collected and is shown on the LCD display screen.

- At the database station, which consists of an ARM processor, data from all the monitoring nodes is collected.
- The collected data is displayed on an LCD display for local monitoring and basic analysis.

4.3 Remote Monitoring Centre

The communication station is made of a Zigbee module--it is equipped to receive data sent from the data base station. By this way raw data is transmitted to server PC having GUI (Graphic User Interface) equipped on it through serial communication. Besides picking up of the information, the collected data is compared with water parameters (standard values). If deviation is noted at any point, SMS message will be automatically delivered to a formally designated person who will immediately take the steps required to prevent further malfunction.

- The remote monitoring center receives the data from the database station through a Zigbee module.
- This data is then forwarded to a server PC with a Graphic User Interface (GUI) via serial communication.
- The GUI allows users to monitor water quality parameters remotely.
- Additionally, the obtained data is compared with preset standard values of water parameters.
- If any parameter deviates from the preset values, an alert system is triggered. This system can send SMS notifications to authorized personnel, prompting them to take necessary preventive measures.

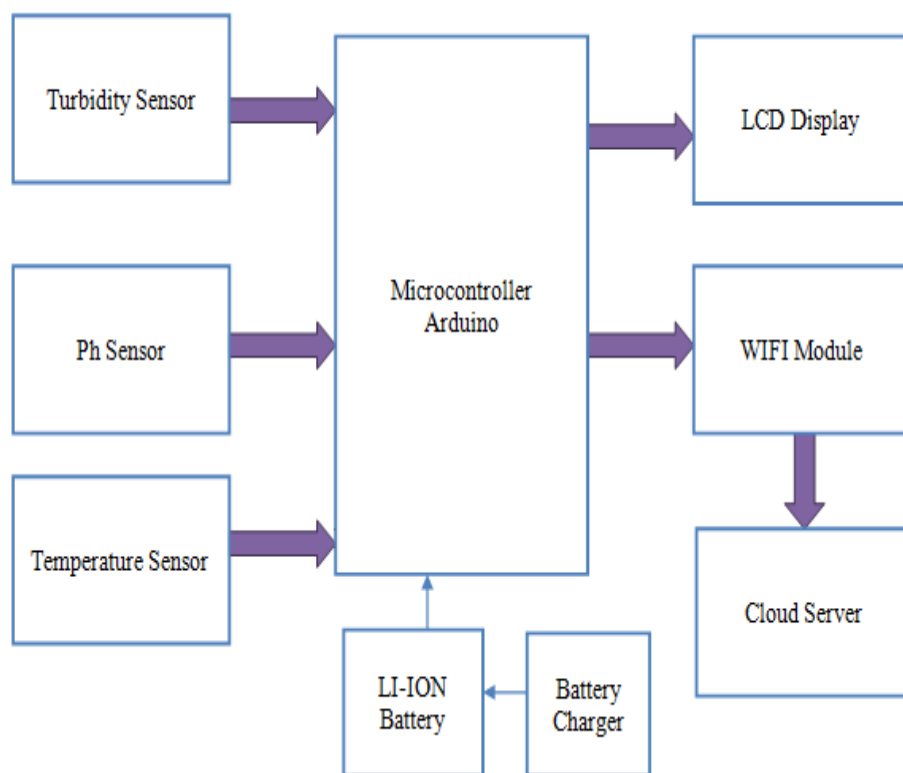


Figure 1 Block Diagram of proposed system

4.4 Internet of Things (IoT) Integration

- The IoT enabled core controller retrieves, processes data and then forwards it to the cloud via the TCP/IP protocol.
- The processed data can be made accessible globally via any browser application through an assigned IP address.
- The IoT environment improves accessibility and real-time monitoring functions, allowing users to remotely check water quality and respond in a timely manner upon occurrence of any problems.

4.4 Wireless Sensor Networks (WSN)

- The system is based on WSN technology which is allowing unattended, continuous monitoring of the water quality in the regions which are hard to reach.
- The standout feature of WSN technology is its low power consumption, affordability, and high precision features which allow it to be able to function for long-term and remote deployments.

Table.1. Description of the components

Components	Description
Arduino Uno	This work will outline an open-source microcontroller on the basis of the 8-bit ATmega238p chip; this microcontroller will serve as the link between the sensors and application described in the study. (It includes other components like a crystal oscillator, digital connection, a voltage source, etc. (An Arduino Uno has sixteen digits: uses of these pins for analog in and, the connection to the universal serial bus (USB), an ICSP header, and a switch for resetting). One of the many contributions of Arduino Uno is the inclusion of an ICSP case.
ESP8266 Wi-Fi Module	The ESP8266 is a small and inexpensive Wi-Fi module which is used to add wireless functionality to the

	electronics projects. This device is very often the element of IoT systems.
LCD Module	The 16x2 LCD module is an electronic module with two rows of 16 characters each and is known to be compact display unit while used widely on the electronics for text-based information. It has four pins for the LCD display: VCC, GND, SDA and SCL pins are connected to the Arduino board.
Turbidity sensor	A turbidity sensor for water detects the amount of light scattered or blocked in a sample by suspended particles, measuring thus the clarity of the water. It greatly meets the purposes of water quality evaluation for diverse purposes, for example water treatment, environmental monitoring, and industrial processes.
pH sensor	Water pH sensor is an electrical device precisely for research of the acidity of water or, commonly, more generally, the water alkalinity. It measures hydrogen ion concentration, giving a pH value which can indicate whether the solution is acidic ($\text{pH} < 7$), neutral ($\text{pH} = 7$), or alkaline ($\text{pH} > 7$). The pH sensors are used, for instance, in water treatment, agribusiness and food processing, among others, to ensure ideal environment and quality control.
NTC 5D-5 thermistor	The NTC 5D-5 thermistor is temperature detector while it is electrically resisting with temperature and it will work on scale for water determining in different applications.
Li-ion battery	A Li-ion battery usually known as a Li-ion battery is a kind of rechargeable energy storage device which is particularly famous for its high power density as well as long life span. It utilizes lithium ions that are involved into the electrochemical energy reactions between the battery's positive and negative electrodes during the charge and discharge cycles.
Cloud Server	A cloud server for water quality management is a centralized information system that keeps the collected data from the water sensors and the values obtained after the analysis of them. The platform also makes water monitoring immediately available.

V. RESULTS AND DISCUSSION

In our model, the collected sensor data will always be kept up-to-date and can be shown on an LCD and a dedicated Android application. These two display techniques are built to give users ease in having water quality info of current location on high level of speed. The LCD screen gives users with real-time local information while the android application is designed to show users with remote accessibility of water quality information.

Users will be able to see sensor data drawn from LCD screen and Android application, making it easy-to-use and user-friendly, through visually presented water quality index. This interface is designed to empower users with the ease of data interpretation and the ability to effectively make decisions on water quality issues.

The system can be further enhanced through integration of the ESP32 microcontroller with wireless connection. The system now permits the users to have access to sensor data remotely which makes it user friendly and easy to use. This connectivity enables users to retrieve the data using any internet-enabled device like a smart phone or tablet either using the mobile app provided for Android.

Blynk software is a strong data visualization and interaction platform for the Android application, which works with it. Users can obtain and assess the collected data automatically from sensor units without any difficulties using customizable interfaces which can be reproduced according to each particular user's need and taste.

Additionally, the collected sensor data will pass through the processing stage to guarantee the accuracy and credibility prior to presenting the user. The processing may involve different types of techniques such as noise filtering, calibration adjustments, or other data refinement methods, in order to obtain accurate information about water quality.

we will now elaborate on the role of Blynk software: this software is an essential tool to undertake the unhindered collaboration between ESP32 microcontroller, cloud storage, and Android application. It gives a rich environment for android app and module development to receive process and visualize sensor data. The application architecture is ensured to be holistic, responsive and efficient in this way.

In all, the system is very cleverly designed to constantly gather process, analyze, and show water quality data on the display screen. It gives continuous monitoring capabilities that could supply timely information for decision making, research, and environmental management.

Water Quality Critical data are utilized in determining and enforcing standards and regulations of water resources, which direct actions and decisions for the betterment of water quality. Table 2 illustrates water quality governance.

Table.2. Water quality governance

Sensor	Good	Moderate	Bad
pH	6 -7	8 – 9	9 -14
Temperature	10-15	15-35	35+
Turbidity	< 5	> 5	> 5

The visual illustration in Fig. 2. demonstrates the live variability of water in terms of temperature that is occurring in different parts. Such a graphical representation helps to identify sudden spikes and regular patterns in terms of temperature changes. This offers a lot of information to specialists and might make some possible environmental impact.

Fig. 3. illustrates pH levels fluctuations in the water body in real time. The visualization gives a clear overall picture, allowing anyone to track the dynamic change of pH which are very good indicators, and can predict the level of water quality and ecosystem health. In addition to this, **Fig. 4.** illustrates fluctuation of turbidity during the day in the water.

The display of turbidity fluctuations in this manner will make the understanding of the current water body conditions easy to evaluate and measure sediment levels, suspended particles and general water quality. The visual representation in **Fig. 2, 3 and 4** gives a comprehensive picture of the temperature, pH and turbidity patterns in the water, leading to informed decisions that will improve water quality monitoring and conservation measures.

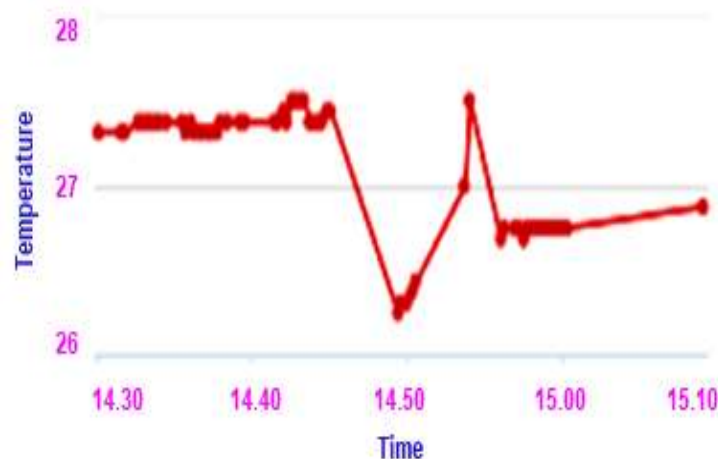


Figure 2 Real time data on temperature fluctuation is plotted in water

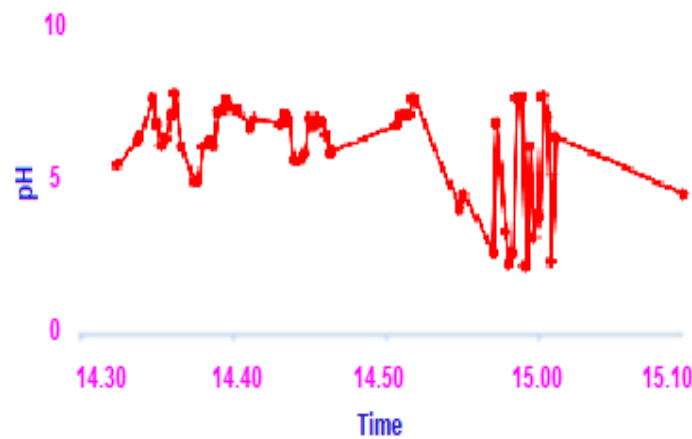


Figure 3 Real time data on pH fluctuation is plotted in water

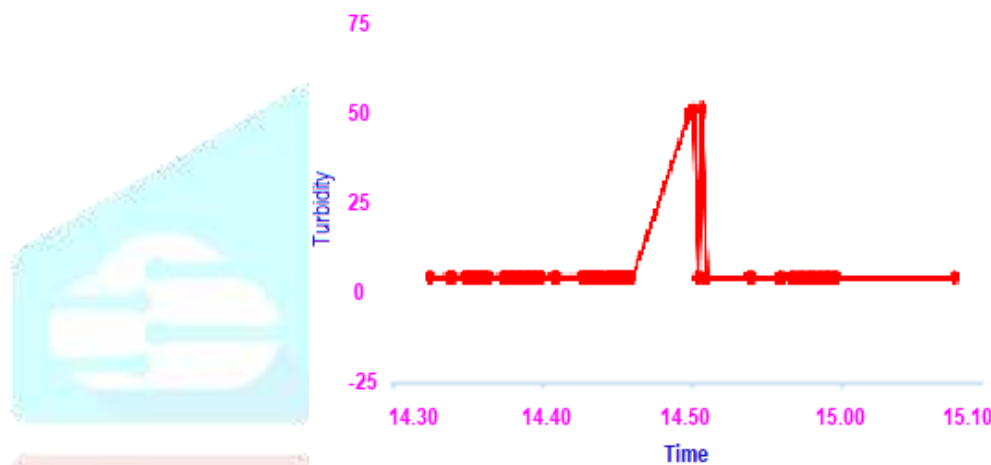


Figure 4 Real time data on turbidity fluctuation is plotted in water

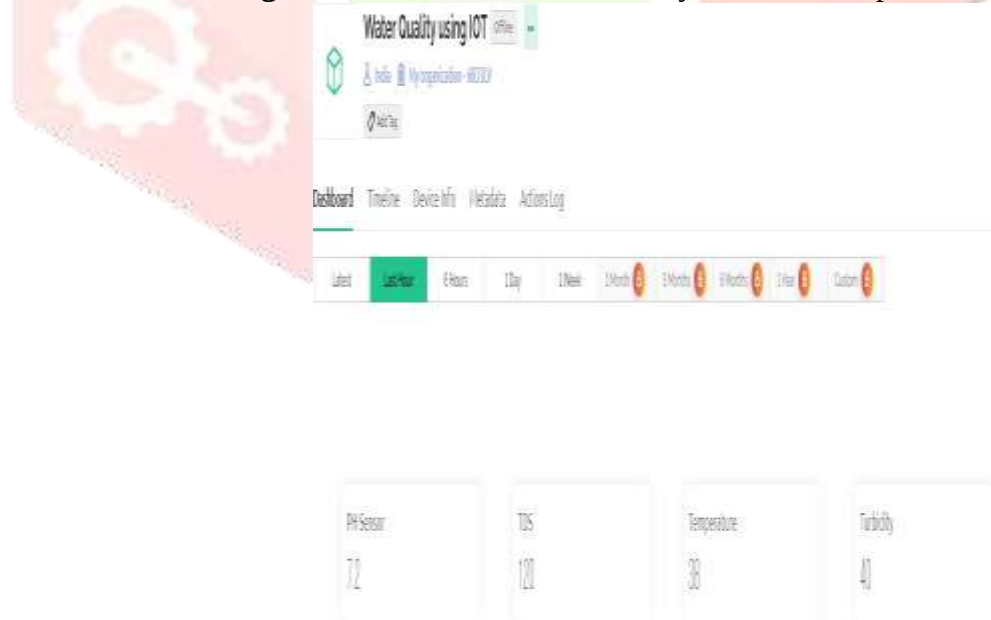


Figure 5 Blynk IOT web application real time sensor readings

VI. CONCLUSION

Our project is dedicated to achieving high-performance, real-time, and accurate analysis of water quality. In our proposed system, we utilize Arduino microcontrollers and various sensors to measure parameters such as Total Dissolved Solids (TDS), temperature, turbidity, and pH levels in water. Looking ahead, we aim to expand our parameter measurements to include conductivity, hardness, chloride, ammonia, iron, fluoride, and other indicators crucial for assessing water purity, especially for drinking and daily use.

The prototype water monitoring system presented in this project leverages IoT technology for enhanced functionality. By incorporating sensors, we collect comprehensive data for analysis, enabling us to devise effective solutions to water-related challenges. This data is transmitted to a cloud server via a Wi-Fi module, specifically the ESP8266, facilitating real-time monitoring and control capabilities. Our application stands as a robust contender in the realm of real-time monitoring and control systems, offering a promising avenue for addressing various water-related issues.

Our system is characterized by its efficiency and real-time monitoring capabilities, made possible through IoT integration. By connecting a central base station and nodes via IoT networks, and interfacing the base station with the internet, users can log in and access real-time water quality data. Looking forward, our future endeavors include the implementation of more efficient routing algorithms to extend the network's coverage to wider areas. Additionally, we plan to integrate additional sensors, such as turbidity, dissolved oxygen, and color sensors, into our system, further enhancing its capabilities and accuracy for comprehensive water quality assessment.

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