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Integrating IoT-Based Water Quality Monitoring with Data Science and Web Technologies

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Abstract: **Water is an essential resource in everyone's life, fresh water is limited and is used in a very huge quantity. Fresh and clean water is very necessary in human life, Water testing is time-consuming and expensive so we bring an idea in which we can provide water testing in real-time. This paper contains information on water testing with the help of a hardware device containing an Arduino UNO microcontroller, the LCD user interface, the liquid flow sensor, the pH sensor, the water level sensor, etc. The paper also shares about collecting water quality from the IOT device and redirecting the data to the website to generate an automated visualization report to get insights and patterns about the water data, the website also includes a feature to predict whether the water is clean to drink or not, the website also provides the user to sell or request water depending upon their need and quality of water. With the help of Data Science and IOT, we want to provide a service to the common people that will help to deal with water-related problems. The Paper gives an overview of the Hardware components, Machine Learning, and Automated data visualization.**

Keywords **- Internet of Things, data science, Automated data visualization, water management, and real-time water quality monitoring.**

I. INTRODUCTION

Water is a very crucial substance on Earth, the planet Earth is also called as "Blue Planet" because of the vast quantity of water present on the planet which is around 71%. The estimated amount of water present is said to be around 1.386 billion cubic kilometers'(km^3) but out of which only 2.5% is freshwater which is found in glaciers, groundwater, lakes, rivers, etc., the rest is covered by Oceans. Of the 2.5 percent, only 1 percent is accessible, even the water contains water (lakes, rivers) where chemicals and wastes are disposed of, which leads to water pollution. From here the quality of water gets degraded. Very few people think about water quality, by drinking bad-quality water, the human body can have chronic waterborne diseases like typhoid, Arsenicosis, Fluorosis, etc. So, to reduce this and make people aware of water quality, we introduce an IoT-based hardware device and a website that will help you to know about the quality of water based on certain parameters.

Even then huge amounts of water are being wasted because of uncontrolled use and exploitation of water resources, so to reduce this water waste and control it we provide a website-based service that will help you to control the wastage of water and supply good quality water to consume. It is known that tankers are used to supply water in water scarcity areas and tanks are made to store the water for a long period, overflowing water tanks are the most common reason for the waste of water. Water tanks are mainly present in residences, schools, colleges, Municipal overhead tanks, Hospitals, etc. It can contribute to a lot of water wastage. If we use IoT-based smart systems, then we can save large amounts of water.

Every freshwater is not drinkable, normally water that is good for drinking should have passed in the following parameters PH., TDS, Turbidity, etc. With the help of Machine Learning, we aim to tell the users whether the water is drinkable. We also aim to provide our users with an automated data report from our website which will give the user a better understanding of the water they consume to drink, bath, etc.

One of the main problems we want to solve is that if the government of India wants to check the water quality of a certain state or region of India, they create a team that surveys that particular region and checks the water quality by going to each water reservoir, this process takes time and costs money. What we want to provide is an IOT-based hardware model that will help the government reduce survey time and give results in real-time which will even help in fast decision-making and even predict future water-related problems.

So our overall aim is to create with the help of IOT and Data Science, a hardware structure with multiple sensors, use Machine Learning to predict water quality for our users, and generate an automated report for better understanding.

II. LITERATURE REVIEW

Innovative techniques are required to test real-time water to come up with a solution to the problem of water pollution. The purpose of this literature review is to determine the ideas, difficulties, advantages, and disadvantages that have been discovered in past studies.

The study Real-Time Water Quality Monitoring System has proposed IoT-based systems for monitoring water quality in real-time. The authors Mithila Barabde, and Shruti Danve have introduced a Sensor-Based Water Quality Monitoring System using wireless sensor networks (WSN) to measure parameters like pH, dissolved oxygen, turbidity, and conductivity with the help of using available sensors at remote places. The proposed system involves data monitoring nodes, a database station, and a remote monitoring station. The challenges we saw in the study were monitoring water quality with IoT devices is tricky because we have to make sure all the sensors work well, even in tough conditions. Also, the way data is transmitted between devices must be strong so everything stays connected and shares information on time. Making sure these systems can grow and don't cost too much is also important. With multiple sensors, maintenance becomes very important so that the device can give an accurate result and increase its life. Past research shows that using IoT for checking water quality works well. These systems can collect data instantly in real-time, which helps us find the result quickly and make decisions fast. Also, using websites to show the data makes it easier for everyone involved to see and use it. But there are some disadvantages too. We have to do maintenance and fix the sensors regularly to make sure they give the right results. Also, because these systems use wireless communication, they can be affected by bad connections or hackers, so we need strong security to protect them [1].

In another proposed study for a water quality monitoring system with the help of IOT, this study Smart Water Quality Monitoring System with cost-effective using IoT by the authors Sathish Pasika, and Sai Teja Gandla present a smart water quality monitoring system using IoT technology. Their system integrates multiple sensors to measure parameters such as pH value, turbidity, water level, temperature, and humidity. The collected data is transmitted wirelessly to a central server using ESP8266 Wi-Fi modules and visualized through a web-based application on ThingSpeak. This research highlights the future of IoT in providing cost-effective and efficient solutions for real-time water quality monitoring. The system enables the collection and analysis of water quality data, which is then uploaded to a server for real-time monitoring. Additionally, GSM technology is used to forward data to mobile users via SMS, enhancing accessibility to water quality information in remote areas. One major challenge of this technology is to measure multiple water parameters accurately. Checking the reliability and accuracy of sensor data in varying environmental conditions remains a significant concern. Secondly, the security and privacy of water quality data transmitted over IoT networks must be addressed to prevent unauthorized access and manipulation. Implementing robust encryption and authentication mechanisms is crucial to safeguard sensitive information [2].

In another study Development Web and mobile application and Open Data Platform for water quality management in Pak Phanang River Basin, the authors created web and mobile applications and an open data platform for the community researchers to use for monitoring the water quality management in Thailand. They also used the mobile and web application to collect and represent WQI data. The study also mentioned that water quality could be evaluated with parameters like dissolved oxygen, electrical conductivity, nitrogen, phosphorus, and pH. They mentioned that In Thailand, increasing population, human activities, and land use activities such as economic, agricultural, and industrial are the major causes of water quality problems. So they aimed to create a web and mobile application and open data platform to improve water quality management in Thailand. [3].

In the last and final study, we saw the paper titled IOT Based Water Quality Monitoring with Android Application which discusses an IoT-based water quality monitoring system that had an Arduino UNO board and various sensors to calculate water quality in real-time. It has parameters like pH, conductivity, temperature, and turbidity sensors to monitor water quality. The Arduino UNO collects data from these sensors and transmits it to ThingSpeak, a cloud-based IoT platform, with an ESP8266 Wi-Fi module. They also had an Android application that enhanced user accessibility by providing a user-friendly interface to access real-time water quality data stored on the cloud platform. Users can monitor parameters with the application easily and visualize trends through graphical representations, which helps in decision-making. [4]..

III. METHODOLOGY

In creating an IOT-based hardware and a website, certain hardware and technologies are used, these technologies are very important in our study to create the project, this section explains different types of hardware components used in creating the model, explains the design and development of the website and which technologies are used to create the website.

A. Hardware Components:

The hardware mentioned in this section is selected carefully based on the IOT device, every single sensor has a specific role in monitoring water quality. The components are:

1. LCD – 16x2 Display: LCD is also called a Liquid crystal display, it is an electronic display that is used in multiple gadgets like mobile, calculators, computers, etc. This particular LCD has 16 pins and 2 rows, where each row has 16 characters and it generally uses 4.7V to 5.3V for operating.

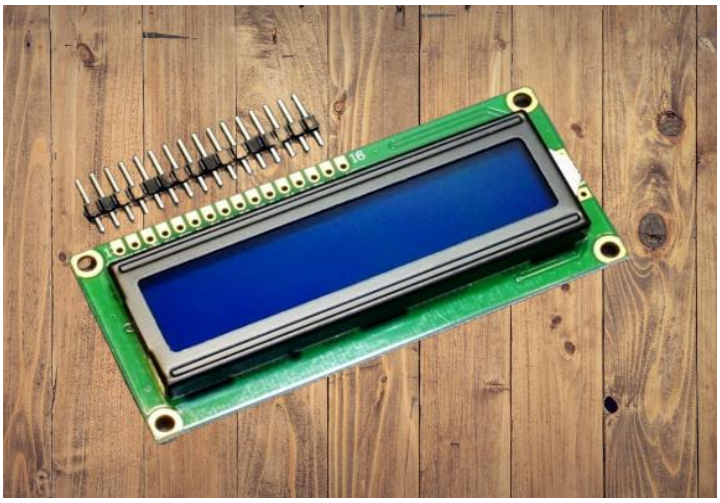

Fig.1. LCD 16x2 Display

2. PH Sensor: PH is the potential of hydrogen, pH is used to measure how acidic or basic the water is, it ranges from 0 to 10 where 7 is neutral, and pH less than 7 means the water is acidic and the pH greater than 7 means the water is on its base side. To check the pH of any liquid substance the pH sensor is used, it is the most important tool for measuring pH and is commonly used for calculating water quality [5].

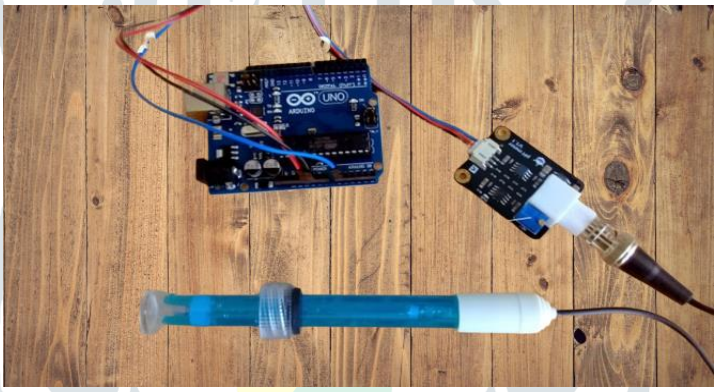

Fig.2. Ph Sensor

3. Liquid flow sensor: A liquid flow sensor is a device used to track fluid flow rate through a pipeline, the sensor works when it is installed between 2 pipelines, and it detects how much water flows through this pipeline. The output reading is produced when the water is continuously flowing through it, if the reading speed is high then the output is high, and vice versa [6].

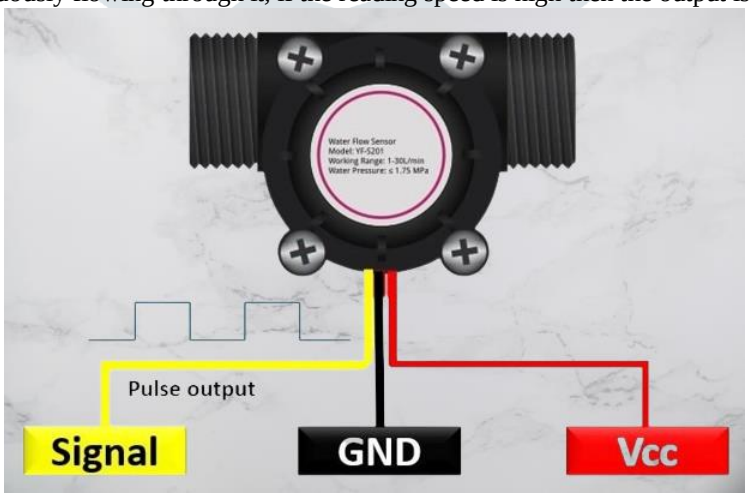

Fig.3. Liquid Flow Sensor

4. Temperature Sensor: The temperature sensor, in our case the DS18B20 temperature sensor is a one-wire digital temperature sensor. It is used to communicate with Arduino. It only needs one data line and GND. It is used to measure the water temperatures. The temperature range of this sensor is from -55°C to +125°C. This sensor has three types of pins which are black, red, and yellow. The black pin is connected to GND, the red is connected to VCC, and the yellow is connected to the digital pin of Arduino [6].

Fig.4. Temperature Sensor

5. Arduino Uno: Arduino UNO is a microcontroller board. It is used in IOT applications due to its ease of use. The microcontroller board has digital and analog input and output puns that can be interfaced with multiple expansions. The board has 14 I/O digital pins and 6 analog I/O pins and it is programmed with Arduino IDE which programming is mostly based on or similar to C/C++ [5].

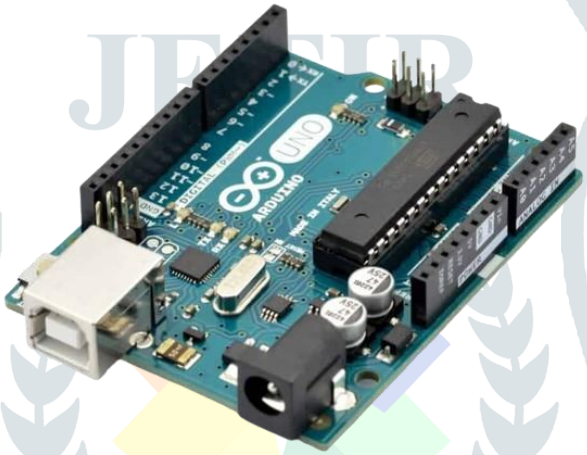

Fig.5. Arduino Uno

6. TDS meter: Total dissolved solids meter or TDS meter is a device that is used to measure the amount of solids dissolved in a liquid. It helps in determining the purity of water. It is generally a portable device and its reading is measured in ppm which is parts per million [5].

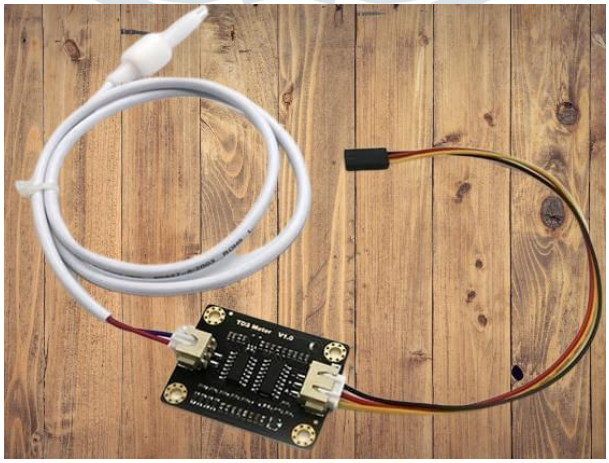

Fig.6. TDS meter

7. Turbidity Sensor: This sensor is used to measure the cloudiness or haziness of water and also measure the number of solids in liquid. It is also called turbidity. Turbidity sensor plays a crucial role in measuring water quality. Its reading is measured in NTU which is nephelometric turbidity units and formazin nephelometric units or FNU [5].

Fig.7. Turbidity Sensor

8. ESP WIFI Module: It is a device that allows the microcontroller to connect with Wi-Fi. It was developed by Espressif Systems, one of the most popular Wi-Fi modules is ESP8266 followed by ESP32. ESP8266 is widely used in IOT projects and embedded systems. It is programmed by using C/C++ [4][5].

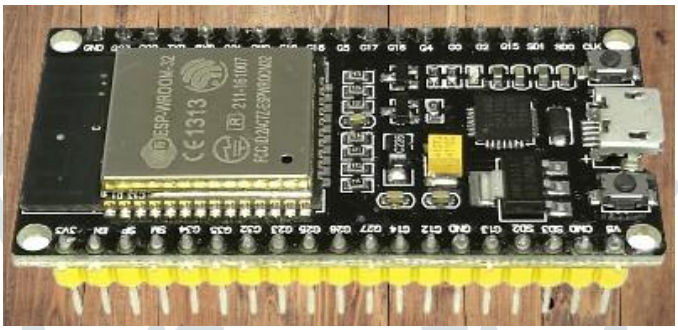

Fig.8. ESP32 WIFI Module

B. Website Design and Development

The website is one of the important features of our project, it helps the users of the IOT model to predict if the water is drinkable or not, and monitor the quality of water, understand the water quality by seeing creative visualization which will be helpful for decision making. The design and development of the website contain a few steps to make sure the website is attractive, user-friendly, and easy to use.

1. Frontend: The website is developed with HTML, PHP, and JavaScript. HTML is used for creating a website structure. PHP is used for server-side scripting which helps in connecting databases and JavaScript is used for creating interactive web pages and gives the user a better experience. So together the combination of HTML. PHP and JavaScript create a user-friendly, interactive, and attractive website.

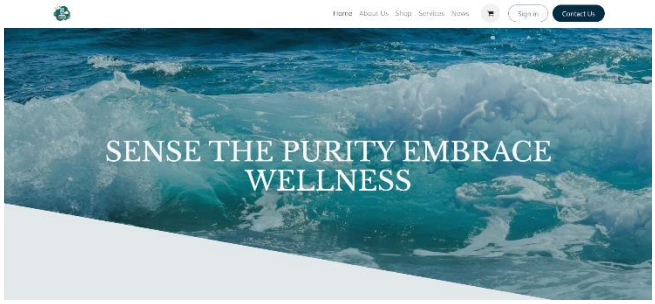

Fig.9. Website Interface

2. Backend: The backend for the website is made with a combination of technologies like Larvel which is a PHP framework that is used to transmit reading from the IOT device to the website, the database used in our case is a relational database, MySQL is a great database to work on due to its compatibility with PHP.

3. Prediction: One of our important features of the project is to classify whether the water is drinkable or not. We will be using a turbidity sensor and TDS meter to get the reading from the water and use machine learning algorithms to determine whether the water is safe for drinking.

4. Automated data Visualization: Another important aspect of the project is that we are providing automated data visualization of the water reading to the users which will act as a report that will give the users a better understanding of the water quality and use for decision-making.

C. Data Transmission

The Arduino is connected to various sensors like the TDS Meter, Turbidity Sensor, ESP WIFI Module, Temperature Sensor, and pH. Sensor, and Liquid Flow Sensor. each sensor gives information related to water quality parameters the Arduino reads all the data from those sensors. The Arduino is connected to the ESP Wi-Fi module which provides internet

capabilities. The Arduino collects data from sensors and transmits that data to the ESP module. The ESP module receives the data from Arduino and transmits it to the server with the help of the internet. The server gets the data from the ESP module, the server processes the data, and stores the data in MySQL database with the help of SQL command. Then the data which is stored in the MySQL database is transmitted to the website which is built from HTML, CSS, JS, etc. [10]..

IV. PROJECT IMPLEMENTATION

The project is made in keeping a few things in mind which are hardware setup, IoT integration, and website development, this section tells in what way the project was implemented.

A. Hardware Setup: The hardware setup of the model was carefully built with different sensors to ensure accurate data collection. These were the following steps in ensuring the hardware structure:

1. Microcontroller Configuration: In this project, we used Arduino UNO as a microcontroller. The Arduino UNO helps in connecting and controlling multiple sensors which will be used in creating the water quality monitoring device. The Arduino UNO is programmed in the Arduino IDE and will be written in C/C++ [7][8].

2. Sensors: The sensors used in the device play a very crucial role in monitoring the water quality parameters and the sensors used here are:
   a) Ph Sensor: It measures the acidity of the water.
   b) Liquid Flow Sensor: It tells the flow rate of the water that goes through a pipeline.
   c) Temperature Sensor: It measures the water temperature.
   d) TDS Meter: The TDS Meter finds the dissolved solids in the water.
   e) Turbidity Sensor: It tells us whether the water is cloudy.

3. Challenges: When the project was being implemented the challenges, we faced were data accuracy, power management, and how to get the reading of all the sensors in all together.

B. IoT Integration: The integration of IoT devices helps transmit water quality-related data which would be very helpful for the server and leads to prediction and analysis:

1. ESP Wi-Fi Module: The Arduino UNO is connected to the ESP Wi-Fi module which allows us to connect to the internet. The ESP module is included to set up a connection to a Wi-Fi network which is wireless, which allows the Arduino to transmit the data over the internet [7][8][9].

2. Data Transmission: The data transmission happens after the connection is established to the Wi-Fi network, the Arduino collects the data from the sensors and transmits the data to the server through the ESP module [10].

3. Storage: The storage of the data is in a relational database management system; in our case, we use MySQL [11].

C. Website Development: The website acts as an interface which is for the users to access, and monitor the water quality data in real-time. It is also for prediction and getting auto-generated reports in real-time for better decision-making.

1. Website Frontend and Backend: The front of the website is made with the help of HTML, PHP, and JS which helps in creating an interactive and attractive interface for the users. The backend part is made with the help of Larval which is a PHP framework, a relational database management system is used which helps in storing the data from the sensors.

2. Data Visualization: The data visualization is done with the help of Python libraries. With the visualization, it is very helpful for the users to get an understanding of the water quality.

3. Machine learning: The concepts of machine learning are used in the project to help in prediction. With the sensor data, we aimed to predict whether the water was safe to drink or not, for that we used binary classification which is a supervised learning concept, with this we predicted the water quality based on certain parameters like Ph value, TDS Value, Temperature, etc. [13].

V. RESULT

The execution of the IoT-based water quality monitoring system provided the results, showing the efficiency in getting the water quality data in real-time on certain parameters. Through various testing and analysis, we gain the following readings:

A. Hardware Performance: This contains the results related to the IoT model:

1. Sensor Reading: Various sensors are joined together to form a hardware device to gain readings of various water quality parameters like Ph Value, TDS Value, Turbidity, Temperature, and Liquid Flow Rate. The constant maintenance will ensure the accuracy and reliability of the sensors that provide the data in real-time.

2. Data Transmission: The microcontroller Arduino UNO successfully transmits the sensor data to the server with the help of the ESP Wi-Fi module. The data will be important for making the predictions which will help make decisions.

B. Website Performance:

1. User Interface: The website's user interface is made to gain real-time water quality data, predict whether the water is safe to drink, and the automated reports. The website is made responsive which ensures the device compatibility which helps the users.

2. Data Visualization: The auto-generated reports have different charts and graphs that will visualize the water quality-related data in a meaningful way. The automated feature will help the user to get the report whenever the user wants to, which will provide insights that will lead to proper decision-making.

3. Prediction: Machine learning algorithms were used to predict whether the water is safe to drink. The prediction accuracy was checked with the evaluation metrics such as precision, F1-score, and recall.

VI. Discussion

The execution of an IoT-based water quality monitoring system mixed with data science, IoT, and Web Technologies presented an important step in addressing water management challenges and solutions. By missing the hardware components with the IoT device and website, we aimed to give real-time insights about water quality, improving decision-making and promoting water conservation.

The hardware device successfully collected accurate data on multiple water quality parameters including pH value, turbidity, temperature, TDS value, and liquid flow rate. The accuracy of the reading is ensured due to the regular maintenance of the sensors which will be effective for the monitoring system. The microcontroller Arduino UNO combined with the ESP Wi-Fi Module, transmitted the sensor data to the server, which helped to monitor the water quality in real-time. The data transmission process is very crucial for perfect analysis.

Combining the different technologies allowed the connectivity between the IoT device and the server for monitoring the water quality parameters. Despite the challenges, we tried to transmit the data over the ESP module to the server accurately. After receiving the sensor data, the server application prepared and stored the data in a relational database management system. The MySQL database stored the data for the project which later helped in generating the report for the users.

We provided an interactive and user-friendly web interface for the users to access the real-time water quality data, data reports, and prediction of the water for safe drinking. We made sure that the website was responsive so that the user finds it multiple device compatible which helps in a better user experience. The appealing charts and graphs used in the automated water quality data report help the user understand the data and find the anomalies. The automated report feature helps the user to get the report in real-time and gives insights related to the water quality trends which helps the users in proper decision-making regarding water consumption and conservation.

We also provided a feature where we predict whether the water is safe to drink or not for that we used machine learning algorithms that accurately classify the water quality based on the data provided by the multiple sensors. Including this in our website will allow the users to get knowledge about the water they consume.

The project is just the beginning of the innovative idea from our collective mind, there are various things we can add in the future which will benefit the users like:

1.Enhancing the sensors: Future concepts of the water quality monitoring system could have advanced sensor technologies to improve data accuracy. We can add more sensors which will add more parameters for the water that will help the users to get more information about the water they use [4][15].

2.Predictive Analysis: Using advanced machine learning techniques, such as predictive analytics could allow the system to predict the water quality trends that will happen in the future and find the potential issues.

3.Mobile Application: We also plan to create a mobile application so our users can use our technology remotely. The mobile application could increase the user engagement [16].

4.Integrating with smart technologies: The world is being introduced with smart technologies every year, we can integrate the system with existing smart meters and water distributors which will help us collect data in large areas. With this, we can help in creating our device more accurately and help our users which will get insights and water usage patterns [17] [18].

In the end, integrating the water quality monitoring system with data science, IoT and web technologies offers a solution to manage water-related challenges. With the help of multiple sensors, a Wi-Fi module, machine learning algorithms, and the website, the water quality monitoring system provides real-time insights into water quality parameters.

VII. Conclusion

In conclusion, making an IoT-based water quality monitoring system with the help of data science and web technologies helped in coming up with the solution to the challenges of water management. In the development and implementation of the device, this study attempted to provide real-time insights into water quality parameters, which will help the users with knowledge about the water they consume. No one should ignore the importance of water as it is a very valuable resource essential for human activities. However clean water is not in large quantities and due to pollution, over-use, and even climate change. To address this challenge, we needed a way to use the technology to monitor and analyze water for our users.

With the help of an IoT device, we developed a hardware setup that had multiple sensors that were capable of measuring a few important water quality parameters like pH, turbidity, temperature, TDS, and liquid flow rate. These sensors integrated with an Arduino UNO microcontroller and ESP Wi-Fi module helped in collecting real-time data and transmission of the data to a server for analysis, prediction, and visualization [3][4].

The website functions as an interface for accessing and monitoring water quality data. Through dynamic visualization, the automated report can help the users to gain water quality trends. The integration of machine learning algorithms enhances the capability of our system by allowing predictive analytics and classification of water quality. Throughout the implementation process, we faced a few challenges which included ensuring the accuracy of data, reliability of sensors, and managing network connectivity. By keeping an eye on the future we also aim to develop our project in a way to enhances the effectiveness of the monitoring system. Advanced technologies give us the potential to expand in such a way that we can have more parameters to judge water and provide detailed reviews.

In conclusion, integrating IoT, Data Science, and Web Technologies represents a very encouraging way to address water management challenges. By collaborating with various technologies and people we can work towards clean and safe water for future lives.

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