Water Quality Monitoring System Based On IOT

Jothimani M Dineshkumar T Gotham Sethu B ThirumuruganV
Assistant. Prof. in Department of ECE, KSRCE TIRUNCHENGODE, Tamilnadu, India
Student in Department of ECE, KSRCE TIRUCHENGODE, TamilNadu,India

Abstract: One of the main concerns for the green globalization is water contamination. Real-time quality monitoring is required to guarantee the supply of drinkable water is secure. We demonstrate the concept and creation of a low-cost device for real-time IOT water quality monitoring.(internet of things).The device, which consists of numerous instruments, is used to measure the water's physical and chemical characteristics. It is possible to gauge the water's characteristics, including its temperature, PH, turbidity, and flow monitor. The central controller is capable of processing the recorded values from the sensors. A central processor can be created using the ESP32 model. Finally, using a Wi-Fi device, the sensor data can be watched online.

Keywords—Internet of things (IOT), pH Sensor, TDS Water quality, DS18B20 Temperature Sensor, ESP32 core, DS18B20 Transistor, DS18B20 Semiconductor, Cloud setup, QUBITRO platform.

I. INTRODUCTION

The 21st century saw a great deal of innovation, but at the same time, pollution, global warming, and other issues were developing. As a result, the world's pollution lacks access to clean drinkable water. Due to the increasing population, limited water supplies, and effects of global warming, real-time tracking of water purity is difficult today. Therefore, improved methods for real-time monitoring of the water quality metrics are required. The variables governing water quality The hydrogen particle abundance is gauged by pH. It reveals whether the water is neutral or corrosive. Water that is pure has a pH value of 7, while water that is corrosive or alkaline exceeds this value. The pH scale runs from 0 to 14. For imbibing, the pH level should be between 6.5 and 8.5. The quantity of undetectable suspended particulates in water is measured by turbidity. The danger of diarrhea increases with sediment, cholera. The sediment must be lower for the water to be pure. A temperature sensor determines how heated or chilly the water is. The water movement through a flow monitor is measured. The manual collection of water samples from various places is one of the conventional ways of monitoring water purity. The remainder of this essay is structured as follows: Section II reviews the related work done for this project, Section III outlines the suggested system with a breakdown of the modules, Section IV offers a schematic circuit with a description of how it operates, Section V displays the findings and a conversation, and Section VI offers a conclusion with a look ahead to future work.

II. LITERATURE SURVEY

a) IOT BASED WATER QUALITY MONITORING SYSTEM

Author Name **:** Sanket Coagula, Aditya Kamate, Sammed Kothale, Pranit Nitave, A.N.Naik(2022).

The Adriano Nan is the foundation of the system. The primary programming device is an Adriano Nano. The system in the suggested idea measures three factors, including PH, turbidity, and water temperature, and uploads the information to a website. The analogue output of the PH sensor is read by the Adriano Nano, which transforms it into the real PH number. The LM 35 output is then received by Adriano, which converts it to the real temperature in degrees Celsius. The TSD-10 sensor's output number is received by the Arduino. The Adriano then shows every value on the LCD. Additionally, it transmits all of the data to a GSM module-accessible website via the internet. All attribute ranges are also programmable. When a measure exceeds its range limit, Arduino sends an SMS warning to the appropriate authority.

b)INTERNET OF THINGS (IOT) BASED WATER QUALITY MONITORING SYSTEM

Author Name: Md. Mahbubur Rahman , Chinmay Bapery, Mohammad Jamal Hossain, Zahid Hassan , G.M. Jamil Hossain, Md. Muzahidul Islam(2020).

Environmental telemonitoring applications have significantly advanced as a result of recent developments in technology, sensing, and Internet of Things (IoT). In the area of aquatic surveillance, research agencies have generally organized static stations or buoys with capabilities for computerized estimation, data recording, and wireless transfer. Several parameters are the main emphasis of this article. comparable to pH, turbidity, temperature, dissolved oxygen, and salinity. Since those factors account for the majority of WQI, we evaluate this parameter. In order to communicate with Adriano, we must first attach instruments (pH, turbidity, temperature, dissolved oxygen, and electrical conductivity). ADC, which converts analogue sensing input to digital data (real-world data), (analog to digital converter). Adriano is used to analyses this info. Then, using serial transmission between Adriano and Node MCU, all digested data is sent to NodeMCU. Character by character transmission is how we transmit info. After that, divide the entire stream of data into distinct data. Parameter info is processed before being sent to Firebase's Real time database. We transfer data in is on format from the Firebase cloud storage and display it on our own website. The online system handles the statistical and decision-making components.

c) *REAL-TIME WATER QUALITY MONITORING SYSTEM*

Author Name: Jyotirmaya Ijaradar, Subhasish Chatterjee (2018).

Our objective is to use Raspberry Pi to create a system for real-time quality evaluation of water health at domestic locations. The factors required to continuously watch the health of the water are collected by pH, turbidity, and temperature sensors. Using instruments to determine the pH, temperature, and particle density of water, among other chemical and physical characteristics of water transfer the gathered data to a Raspberry Pi, present it on a monitor, and then transfer it via a wired or wireless channel to a cloud-based database. Set off an alert if there are any water quality anomalies. Using cloud-based visualisation tools for data processing and visualisation.

d) *PROBLEMSTATEMENT*

For the green economy, one of the greatest concerns is water pollution. Real-time quality monitoring is necessary to guarantee a secure source of drinkable water. We show a concept and creation of a low cost system for real-time IOT water quality tracking in this project.(internet of things). Multiple instruments are used in a device to measure the physical and chemical characteristics of the water. You can gauge the water's characteristics, including its temperature, PH, turbidity, and flow measurement. The central controller is capable of processing the sensor-measured data. One option for a central processor is the ESP32 model. The sensor data can finally be watched online using a WI-FI device.

The 21st century saw a great deal of innovation, but at the same time, pollution, global warming, and other issues were developing. As a result, the world's pollution lacks access to clean drinkable water. Due to the increasing population, limited water supplies, and effects of global warming, real-time tracking of water purity is difficult today. Therefore, improved methods for real-time monitoring of the water quality metrics are required. The variables governing water quality The hydrogen particle abundance is gauged by ph. It reveals whether the water is neutral or corrosive. pH values range from 7 for pure water to more than 7 for alkaline. pH levels vary from 0 to 14. 6.5 to 8.5pH is the ideal range for imbibing purposes. Turbidity is a measurement of the abundance of undetectable suspended particulates in water. Collera, the danger of dysentery increases with turbidity. Turbidity levels below zero indicate pure water. A temperature monitor determines whether the water is warm or frigid. Water movement through the flow gauge is measured by the sensor. Water samples must be manually collected from various places as part of the traditional ways of monitoring water quality. This essay's remainder is structured as follows: section II review the related work of this project, section III describes the proposed system with the modules explanation, section IV provides the Schematic circuit with it working, Section V shows the result and discussion, section VI the conclusion with future scope.

III. PROPOSED SYSTEM

The ESP32, a very low power controller that also includes Wi-Fi and Bluetooth connectivity, is used in this suggested system to enable simple contact with the outside world. And because the controller in our build uses the Deep Sleep technique, we can immediately use this device with an external 5V battery for almost a month on a single charge.

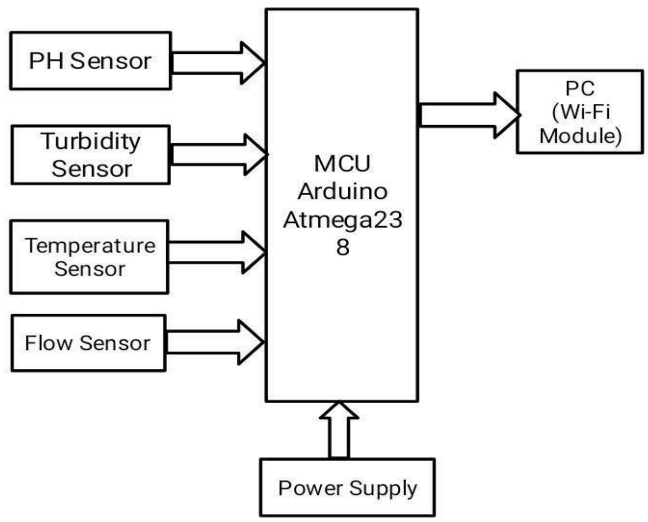

Fig1.Proposed Block Diagram

We use PH, turbidity, and temperature instruments for water quality measurements. Additionally, all of the instruments operate on 5V DC. Using the Wi-Fi protocol, all instrument data are transmitted to the outside world. In order to share the data with other people and the outside world, we created a very lightweight cloud service.

We discuss the idea behind real-time water quality monitoring in an internet of things world. The suggested method's general block diagram is described. Each and every system component is thoroughly described. Several instruments (temperature, pH, turbidity, and flow) are linked to the central processor in the suggested block layout. In order to transmit data over the internet, the central processor accesses the sensor readings and processes them. The central processor is Arduino. On the internet Wi-Fi device, the sensor data can be watched.

a) HARDWARE DESCRIPTION

pH Sensor: One of the most crucial devices that is frequently used for water readings is a pH monitor. This kind of monitor can determine how much acidity and alkalinity is present in water and other liquids. When used properly, pH monitors can guarantee a product's safety and quality as well as the operations that take place in a factory or wastewater facility.

The typical pH scale is depicted by a number that can vary from 0 to 14. A material is regarded as neutral when its pH number is seven. Greater levels of alkalinity are represented by substances with pH values above seven, whereas greater levels of acidity are thought to be present in substances with pH values below seven. For example, toothpaste usually has a pH number between 8 and 9. Stomach acid, on the other hand, has a pH number of two.

Any business that makes use of a cooling tower, boiler, manufacturing procedures, swimming pool management, or other kinds of environmental tracking must understand the distinction between an alkaline substance and an acidic substance. The average pH of the human body is 7.4, which is necessary for the body to function properly. The body will attempt to revert to the neutral condition if its composition ever shifts too far in either direction (too acidic or too alkaline). A pH monitor will enable you to maintain pH levels at a level most suitable for the procedure, regardless of the application. This could be anything from caustics to powerful acids. In the process of measuring liquids, there are numerous pH sensor kinds that you can buy for your purpose, including.

1. A reference electrode and a measuring electrode are both used in a combo pH monitor. The measuring electrode is made to identify any variations in pH value while the reference electrode is used to provide a steady signal.

2. A metal ground electrode makes up the third of the three unique electrodes that make up differential sensors. The ability of these instruments to avoid reference contamination makes them special.

3. Combination sensors housed in plastic casings and 12mm glass can be used to create laboratory sensors. For simpler tasks like pool tracking and environmental sampling, these devices are made.

4. Process pH monitors have built-in constant pH monitoring and are composed of combination sensors. Before buying one of these sensors, you should completely grasp that distinct pH sensors are designed for various applications.

pH Sensors for Quality Water: A pH monitor, which has a range of 0 to 14, aids in determining the water's acidity or alkalinity. Water begins to turn more corrosive when the pH value falls below seven. Any figure over seven indicates a higher acidity level. The way that each sort of pH monitor measures the water's data quality varies. Water purity can be determined in part by its pH . Indicators of conduit rust, solids build up, and other hazardous industrial process by products can also be found by measuring pH.

The pH's fluctuation in a natural situation may also be an early sign of rising pollution. The water would be regarded as hard if the pH level rose above 8.5, which would probably lead to the formation of scale in furnaces and pipelines. As stated, there are four major categories of pH sensors from which to choose: combination sensors, differential sensors, laboratory sensors, and process sensors. Each category is appropriate for a particular application.

Combination pH Sensors: The most widely used sensor is a hybrid pH sensor, primarily because this kind of sensor can serve as the foundation for the development of laboratory sensors and process sensors. Two distinct electrodes, a reference electrode and a monitoring electrode, are included in this electrochemical sensor. The detecting electrode will determine whether there have been any recent changes in the pH level while the reference electrode concentrates on maintaining the signal stability when you capture the pH level.

The technology with combination pH sensors is mainly used at Sensors to create process and laboratory instruments. The technology's extreme versatility is this sort of sensor's finest feature. The two electrodes can perform the most crucial tasks of reading and quantifying the pH levels of water, ensuring that you get fast and precise readings.

Differential pH Sensors: Differential pH sensors have three conductors, which makes them operate somewhat differently from combo pH sensors. The first two electrodes are identical to those found in combination sensors, but the third electrode—a metal ground electrode—can be very helpful in preventing reference contamination. Because of its third wire, this kind of sensor is regarded as a heavy-duty sensor. The use of a third electrode serves as a buffer for the measuring electrode, ensuring an accurate measurement even when contamination happens. A normal pH monitor can become tainted whenever the pH levels shift. As a result, these instruments should last longer and are perfect for demanding industrial and wastewater uses.

Laboratory pH Sensors: Although they are housed in plastic bodies and 12mm glass, laboratory pH monitors use a mix of pH sensor technology. For light uses, such as study and teaching, pool tracking, and outdoor sampling, these compact instruments are ideal. These devices are incredibly adaptable. The joints, wires, and sensor fill can all be customised to meet your specific application requirements if you're looking for a laboratory sensor.

Fig2. pH Sensors

The three types of laboratory sensors that are accessible to you when looking for the best one are fundamental, advanced, and research. Basic instruments like the pH1000 are reliable and simple to use, making them perfect for use in hydroponics, tanks, and swimming pools. Advanced sensors are ideal for effluent and environmental monitoring because they can be used with a range of sample kinds, such as the pH2000. The pH3000 is a research-grade gauge that is best suited for low ionic samples, such as those used in potable water and pharmaceutical uses.

*Process pH Sensors***:** Process pH monitors have bigger, more robust bodies that use combo sensor technology. These sensors also have a process link, which makes them ideal for tracking the pH levels of your water continuously. These sensors can be installed straight into a conduit or put inside a tank due to their high level of durability. The three types of process sensors include moderate sensors, moderate to heavy-duty sensors, and heavy-duty/coating sensors that can be configured with a flat bulb glass, which many people consider a self-cleaning design, whether you want to use the sensor for industrial source water, process water, or wastewater monitoring. This form of water quality management enables you to eliminate impurities from intake water before this water is used in a variety of various manufacturing processes, especially when it comes to water per-treatment for manufacturing reasons. The efficacy of your operations will increase, as will the effectiveness of your heating and cooling systems, and you'll be better able to keep conformance with the required water quality standards. The advantages of having an effective tracking system in place can be many and include.

TDS Sensor: Water's capacity to transmit an electric current is known as its electrical conductivity, or EC. Salts or other particles that have positive and negative charges. The EC of water is calculated using salinity and total dissolved solids (TDS), which aids in determining the cleanliness of the water. The conductivity decreases with increasing water purity. For instance, salt water is a very effective electrical carrier whereas purified water is almost a barrier.

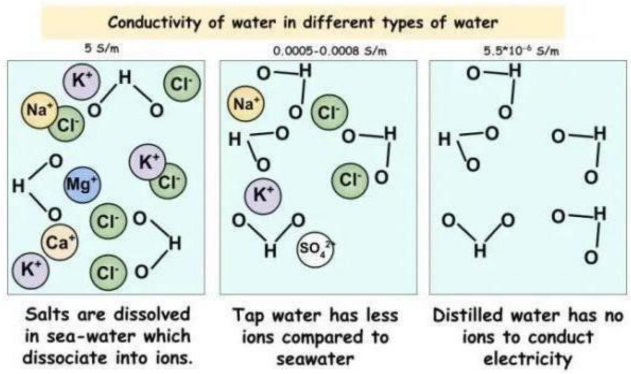

Fig3.TDS Water Quality

The Analog TDS Sensor is a TDS sensor/Meter Kit that works with Adriano and measures the TDS content of water. It relates to the monitoring of water purity. This device is compatible with 5V or 3.3V control systems or boards because it allows a broad voltage input range of 3.3 to 5.5V and an analogue voltage output range of 0 to 2.3V.

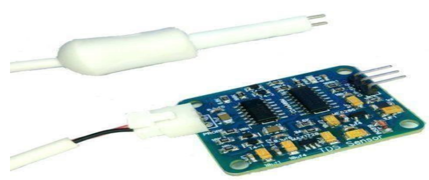

Fig4.Analog TDS Sensor

The stimulation source is an AC signal, which successfully shields the probe from polarization and increases the probe's lifespan while also enhancing output signal stability. Waterproof, the TDS sensor can be submerged for extended periods of time measurement. The instrument has a 10% FS (25 °C) precision and a TDS measurement range of 0 to 1000 ppm. The sensor cannot be used in water that is warmer than 55 degrees Celsius.

Fig5.TDS Probe

DS18B20 Temperature Sensor: A pre-wired and waterproofed variation of the DS18B20 sensor is available. When you need to measure something far away or in wet circumstances, it comes in useful. The sensor can detect temperatures in the range of -67°F to +257°F (55°C to 125°C). PVC is used to cover the wire. Datasheet for the DS18B20 sensor is available here. Since it is digital, even over vast distances, there is no transmission degradation. These 1-wire digital temperature monitors are reasonably accurate, with an average error of 0.5°C. The built-in digital-to-analog translator can provide accuracy up to 12 bits. Any microcontroller with a single digital port can use them with tremendous success.

Fig6.DS18B20 Temperature Sensor

Dallas Semiconductor Corp.'s DS18B20 sensor, also known as a 1-Wire® digital temperature sensor, communicates with the micro processor using only one data line (and GND). As there are no other components needed other than a 4.7k ohm resistor that is linked in series to the data port from a 5V supply, it is therefore simple to connect it with Adriano and other micro controllers that take up only one GPIO pin.

Power supply: There are two ways it can be fuelled. One method uses an external power source with a VCC range of 3 to 5.5V, and the other uses the 16 Data line, also known as parasite mode, in which the sensor's VCC is attached to GND and power is obtained via the data port. When measuring temperature, 1mA of electricity is used.

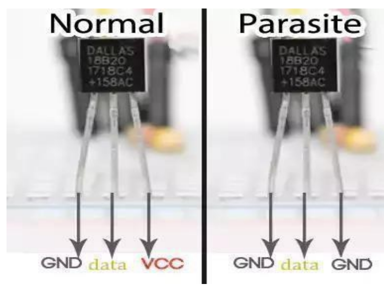

Fig7.Semiconductor

Wire Connection interface: Since each DS18B20 temperature sensor is made with a distinct 64-bit serial code, it is simple to distinguish between them when they are linked via a single 1-wire bus, or when numerous sensor data pins are connected to a single GPIO pin of an Adriano or other microcontroller. Consequently, it is simple to determine the temperature readings from various sensors using a single data bus. Create a digital thermometer with an Adriano and an LM35.

Precision control: The Precision of the DS18B20 sensor can be configurable through the code as parameters 9,10,11 and 12 (bits) to get the precision 0.5°C,0.25°C, 0.125°C, and 0.0625°C, respectively. By default it is set to 12 bits which the highest precision offered by the sensor. Can be adjusted with the help of set Resolution () function which takes the above parameters.

DS18B20 pin diagram**:** There are two variants, a waterproof version and a transistor type version, as shown in the pin out schematic above. And both have three pins: one for DATA, two each for VCC and GND. The transistor type's wires are arranged as follows. 3. VCC, 2.DATA, and 1.GND. Red, Black, and Yellow are the colours of the wires that correspond to the connectors in the waterproof form.

Fig8.DS18B20 Transistor

ESP32 Micro Controller: A line of semiconductor microcontrollers called ESP32 was created by ESPRESSIF. Why are they so well-known? Primarily due to the following characteristics

• Low price: An ESP32 can be purchased for as little as $6, making it readily available to the general population.

• Low-power consumption: The ESP32 uses a small amount of power when compared to other micro controllers, and it enables low-power mode states like deep slumber to conserve energy.

• Wi-Fi capabilities: The ESP32 can easily join a Wi-Fi network to access the internet (station mode), or it can set up its own Wi-Fi wireless network (access point mode) so that other devices can connect to it. This is crucial for IoT and home automation projects because it allows multiple devices to communicate with one another over Wi-Fi.

• Bluetooth: The ESP32 supports both Bluetooth Low Energy (BLE) and Bluetooth Classic (BT), which is helpful for a broad range of Internet of Things (IoT) apps. Dual-core: most ESP32 are dual-core— they come with 2 Xtensa 32-bit LX6microprocessors: core 0 and core 1.

• Comprehensive auxiliary input/output interface: The ESP32 enables a broad range of peripheral input (reading data from the outside world) and output (sending commands/signals to the outside world), including capacitive touch, ADCs, DACs, UART, SPI, I2C, PWM, and many others.

• Support for the Adriano "programming language": If you're already comfortable manipulating the Adriano board, you'll be glad to hear that you can do the same with the ESP32.

ESP32 Specifications: If you want to get a bit more technical and specific, you can take a look at the following detailed specifications of the ESP32 .

Fig9.ESP32

• Wireless connectivity Wi-Fi : 150.0 Mbps data rate with HT40.

• Bluetooth: BLE (Bluetooth Low Energy) and Bluetooth Classic.

- Processor: Ten silica Tense Dual-Core 32-bit LX6 microprocessor, running at 160 or 240 MHz.

Memory:
- ROM: 448 KB (for booting and core functions)
- SRAM: 520 KB (for data and instructions)
- RTC for SRAM: 8 KB (for data storage and main CPU during RTC Boot from the deep-sleep mode)
- RTC slow SRAM: 8KB (for co-processor accessing during deep-sleep mode) eFuse: 1 Kbit (of which 256 bits are used for the system (MAC address and chip setup) and the remaining 768 bits are set aside for client apps, such as Flash- Encryption and Chip-ID). Internal connections for embedded memory include IO16, IO17, SD_CMD, SD_CLK, SD_DATA_0, and SD_DATA_1 on ESP32-D2WD andESP32-PICO-D4.
- 0 MI (ESP32-D0WDQ6, ESP32-D0WD, and ESP32- S0WDchips)
- 2 MiB (ESP32-D2WD chip)
- 4 MiB (ESP32-PICO-D4 SIP module)

Low Power: ensures that you can still use ADC conversions, for example, during deep sleep.
Peripheral Input/output
- peripheral interface with DMA that includes capacitive touch
- ADCs (Analog-to-Digital Converter)
- DACs (Digital-to-Analog Converter)
- I²C (Inter-Integrated Circuit)
- UART (Universal Asynchronous Receiver/Transmitter)
- SPI (Serial Peripheral Interface)
- I²S (Integrated Inter chip Sound)
- RMII (Reduced Media-Independent Interface)
- PWM (Pulse-With Modulation)
- Security: hardware accelerators for AES and SSL/TLS

Main Differences between ESP32 and ESP8266**:** Previously, we mentioned that the ESP32 is the ESP8266 successor. The main differences between ESP32 and ESP8266 boards.

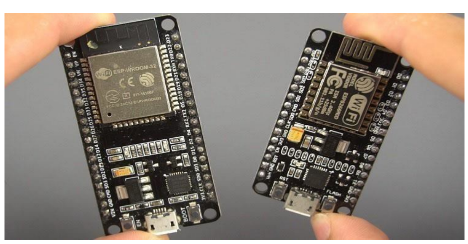

Fig10.ESP32 & ESP8266

The ESP32 boosts the number of GPIOs, adds a second CPU component, and enables Bluetooth 4.2 and Bluetooth low energy. A built-in Hall Effect sensor and touch-sensitive pins are also included with the ESP32, which can be used to bring it up from a profound slumber. Although the ESP32 is marginally more expensive, both devices are inexpensive. The price of the ESP8266 can range from $4 to $6, while the price of the ESP32 can range from $6 to $12 (although this really relies on where you purchase them and which model you choose).

- The ESP32 is faster than the ESP8266.
- The ESP32 comes with more GPIOs with multiple functions.
- The ESP32 supports analog measurements on 18 channels (analog-enabled pins) versus just one 10-bit ADC pin on theESP8266.
- The ESP32 supports Bluetooth while the ESP8266 doesn't.
- The ESP32 is dual-core (most models), and the ESP8266 is single core.
- The ESP32 is a bit more expensive than the ESP8266.

WORK FLOW

a) *Cloud Setup*

Any wireless IoT device, including those for weather tracking, must be built on a cloud platform. A cloud needs to meet a few requirements in order to be effective and dependable. Users can create a straightforward, dependable, and affordable online option using Qubitro. The connection possibilities offered by Qubitro are among its most significant characteristics. What about a cloud provider that provides all integration choices, from Lora to HTTP? Some cloud solutions only support MQTT, others only support TTN, and still others only support HTTP. There are several ways to integrate Qubitro into your system. We do have a cloud provider, but in order to build a personal application or to watch or share your IoT data with others, you'll need an API that enables this. You can do whatever you want with your info because Qubitro has its own API services.

b) *CONFIGURING THE QUBITRO PLATFORM*

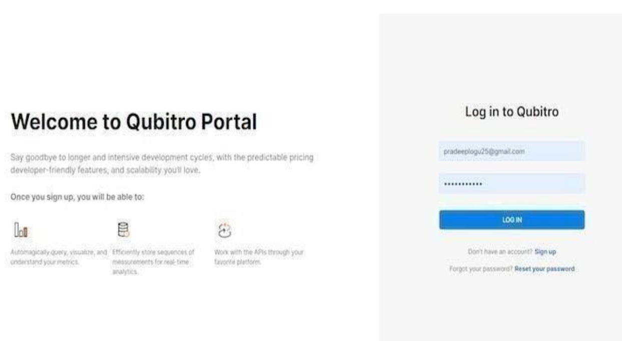

Fig11.Login Page

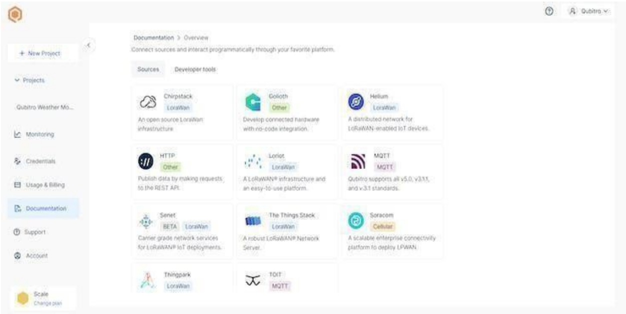

Fig12.Section Of The Project

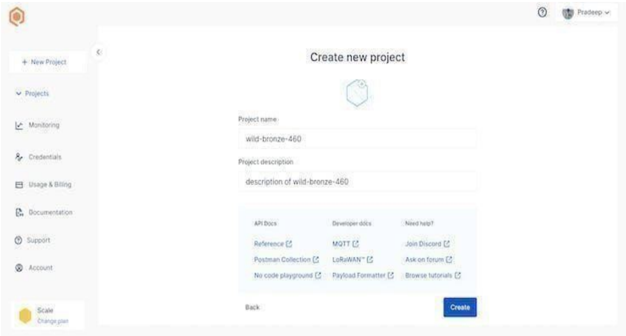

Fig13.Creating New Project

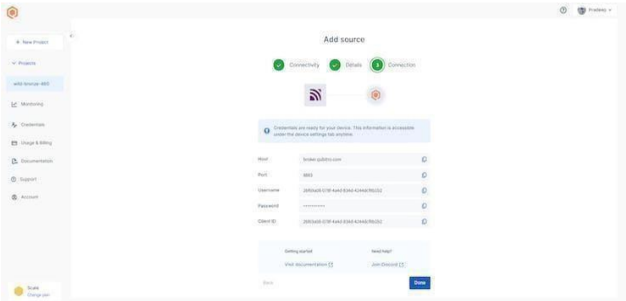

Fig14.Setup Page

V.CIRCUIT DIAGRAM

Let's connect the DS18B20 temperature sensor and analogue TDS sensor to the ESP32 board now. Because the temperature measure is necessary for Electrical Conductivity EC Value compensation, we are using a temperature monitor. The EC readings fluctuate significantly as the temperature rises and falls. Connect the ESP32's 3.3V and GND pins to the TDS and temperature sensor's VCC and GND pins, respectively. Connect the ESP32 A0 port, or the GPIO36 Pin, to the TDS Sensor's output analogue port. In a similar manner, attach the DS18B20's output to the ESP32's IO14 Pin. It is essential to link the DS18B20 output pin and 3.3V VCC as a parasitic power source and draw a 4.7K resistor.

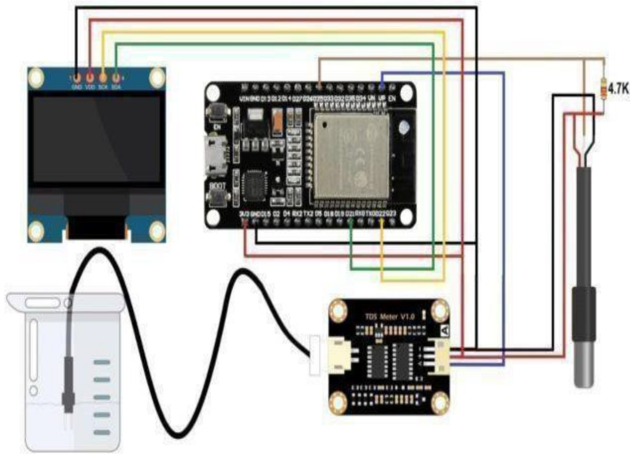

Fig15. Connection Diagram

a) Working Module

The ESP32 will attempt to join to the Wi-Fi network after the code has been uploaded to the ESP32 Board. It will begin receiving the EC & Temperature readings from the Sensor once it has established a connection to the Wi-Fi network. To view those numbers, open the Serial Monitor.

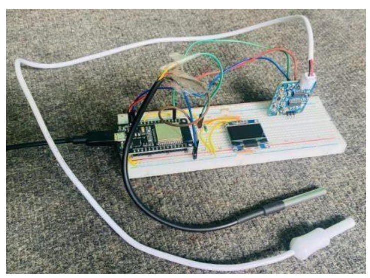

Fig16.Working Module

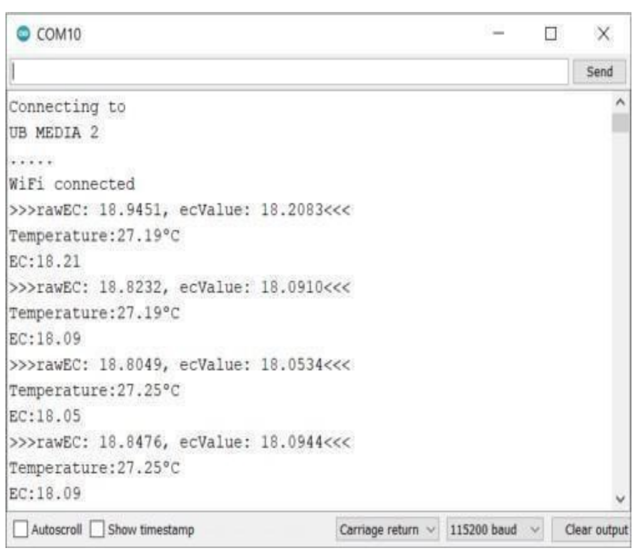

Fig17.Output Page

b) Cloud Pannel Image

Fig18.Cloud Pannel Image

IV RESULTS AND DISCUSSION

The capabilities of the various sensor devices and other components that make up the appropriate implementation model that we have found are depicted in the figure. The ATMEGA 328 with the Wi-Fi module was used in this execution plan. The embedded gadget is connected to the internet by an ADC and Wi-Fi module incorporated in. ADC converts the corresponding sensor data to its digital value, and from that value, the corresponding environmental parameter is assessed. Sensors are attached to an Arduino UNO board for tracking. after gathering information from various monitoring devices positioned in a specific region of interest. When a good connection is made with the server device, the sensed data is immediately sent to the web server.

V CONCLUSION

Water sensing sensors with a special benefit and an established GSM network are used for the monitoring of turbidity, PH, and temperature of water. The device can autonomously check the quality of the water, is inexpensive, and does not need staff to be on patrol. Testing the purity of the water should therefore be more affordable, practical, and quick. The method is very adaptable. Other water quality factors can only be monitored using this method by changing the appropriate sensors and software programmers. The process is easy. It is possible to extend the system to track hydrologic flow, atmospheric pollution, industrial and farming output, and other things. It has a broad range of uses and extension worth Keeping embedded devices in the environment for surveillance allows the ecosystem to defend itself. For data collection and processing, it is necessary to place sensor devices in the surroundings. We can make the surroundings more realistic by placing sensing devices there. Through the network, it can communicate with other things. The user will then have access to the gathered data and the studies' findings via Wi-Fi.

REFERENCES

[1] Nikhil Kedia, Water Quality Monitoring for Rural Areas- A Sensor Cloud Based Economical Project, in 1st International Conference on Next Generation Computing Technologies (NGCT-2015) Dehradun, India, 4-5 September 2015. 978-1-4673-6809-4/15/$31.00 ©2015 IEEE.

[2] C.Nagarajan and M.Madheswaran - 'Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter' - Journal of ELECTRICAL ENGINEERING, Vol.63 (6), pp.365-372, Dec.2012

[3] M.Kannan, R.Srinivasan and G.Neelakrishnan, "A Cascaded Multilevel H-Bridge Inverter for Electric Vehicles with Low Harmonic Distortion", International Journal of Advanced Engineering Research and Science, November 2014; 1(6): 48-52.

[4] Jayti Bhatt, Jignesh Patoliya, Iot Based Water Quality Monitoring System, IRFIC, 21feb,2016.

[5] C.Nagarajan and M.Madheswaran - 'Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis'- Springer, Electrical Engineering, Vol.93 (3), pp.167-178, September 2011.

[6] G.Neelakrishnan, M.Kannan, S.Selvaraju, K.Vijayraj, M.Balaji and D.Kalidass, "Transformer Less Boost DC-DC Converter with Photovoltaic Array", IOSR Journal of Engineering, October 2013; 3(10): 30-36.

[7] Michal lom, ondrej priby & miroslav svitek, Internet 4.0 as a part of smart cities,978-1-5090-1116-2/16/$31.00 ©2016 IEEE.

[8] C.Nagarajan and M.Madheswaran - 'Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques'- Taylor & Francis, Electric Power Components and Systems, Vol.39 (8), pp.780-793, May 2011.

[9] R.Baskar, R.Jayaprakash, M.Balaji, M.Kannan, A.Divya and G.Neelakrishnan, "Design of Nanoscale 3-T DRAM using FinFET", IOSR Journal of Electrical and Electronics Engineering, November-December 2013; 8(1):1-5.

[10] Zhanwei Sun, Chi Harold Liu, Chatschik Bisdikia_, Joel W. Branch and Bo Yang, 2012 9th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks (SECON), 978-1-4673-1905-8/12/$31.00 ©2012 IEEE.

[11] Nagarajan and M.Madheswaran - 'Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis'- Iranian Journal of Electrical & Electronic Engineering, Vol.8 (3), pp.259-267, September 2012

[12] Nagarajan C., Neelakrishnan G., Akila P., Fathima U., Sneha S. "Performance Analysis and Implementation of 89C51 Controller Based Solar Tracking System with Boost Converter" Journal of VLSI Design Tools & Technology. 2022; 12(2): 34–41p.

[13] Sokratis Kartakis, Weiren Yu, Reza Akhavan, and Julie A. McCann, 2016 IEEE First International Conference on Internet-of- Things Design and Implementation, 978-1-4673-9948-7/16 © 2016IEEE.

[14] Mithaila Barabde, shruti Danve, Real Time Water Quality Monitoring System, IJIRCCE, vol 3, June 2015.

[15] Akanksha Purohit, Ulhaskumar Gokhale, Real Time Water Quality Measurement System based on GSM , IOSR (IOSR-JECE) Volume 9, Issue 3, Ver.V (May - Jun. 2014).

[16] Eoin O'Connell, Michael Healy, Sinead O'Keeffe, Thomas Newe,and Elfed Lewis, IEEE sensors journal, vol. 13, no. 7, July 2013, 1530-437x/$31.00 © 2013 IEEE.