IOT BASED WATER QUALITY MONITORING WITH ESP32

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Abstract

Water pollution is a growing concern, as it can have negative effects on both human health and the environment. Detecting and addressing water pollution in a timely manner is essential to prevent serious consequences. Therefore, there has been a growing interest in developing smart solutions for real-time water pollution monitoring. These solutions leverage advancements in sensor technology, communication, and the Internet of Things (IoT). In this paper, we provide an overview of recent works in this field and propose a cost-effective and efficient IoT-based system for monitoring water quality. Our system continuously monitors key quality parameters and sends data to a cloud server for analysis and action. To validate our model, we tested it using three water samples. By implementing such intelligent monitoring systems, we can ensure the supply of clean water and mitigate the negative impacts of water pollution on both human health and the environment.

***Index Terms*— Water quality, Arduino, IoT, pH sensor,Esp32.**

I.INTRODUCTION

Water pollution is a widespread issue that can negatively impact various water bodies, including lakes, rivers, oceans, and groundwater sources. To ensure the safety of marine life, wireless oxygen sensor networks can be utilized to monitor water quality. By detecting pollution levels and oxygen concentrations, appropriate water purification measures can be taken. In this regard, our convenient oxygen focus identification system surpasses traditional methods [2], and it can instantly alert users through the screen interface. Furthermore, it is crucial to note that major water pollutants can include viruses, bacteria, parasites, pharmaceuticals, fertilizers, pesticides, nitrates, fecal waste, phosphates, radioactive substances, and plastics. These substances may not necessarily alter the color of water, but they can still be present as unseen impurities[1].

Water quality can be assessed by examining small amounts of water from various sources and marine organisms. The deterioration of water quality can have significant negative impacts on public health, the environment, and the economy. According to David Malpass, the president of the World Bank, declining water quality is hindering economic growth and exacerbating poverty in numerous countries [6]. For instance, if the biological oxygen demand (BOD) level surpasses a certain threshold, which is an indicator used to measure organic pollution in water, the gross domestic product (GDP) growth of surrounding constituencies with water reservoirs can be reduced by up to a third. Water pollution or poor water quality can have various consequences, including:

Water pollution has a devastating impact on aquatic ecosystems, leading to the destruction of biodiversity and disrupting the natural food chain. Excessive nutrients in the water can promote the uncontrolled growth of phytoplankton, which can harm other aquatic organisms by depriving them of oxygen and blocking sunlight. Additionally, fishing in polluted water sources and the use of wastewater for agriculture and livestock can introduce toxins and contaminants into the food chain, making food unsafe for consumption. Water pollution can lead to a scarcity of clean drinking water, which can have severe consequences for both rural and urban areas. If the quality of drinking water is not maintained, it can lead to public health issues and a lack of access to sanitation. Waterborne diseases caused by contaminated water sources can lead to severe illnesses and even death. According to the World Health Organization (WHO), approximately 2 billion people around the world lack access to clean water sources and are forced to consume water that is contaminated with fecal matter, leading to the spread of various diseases. There are a variety of diseases associated with contaminated water, including diarrheal diseases that can lead to the death of almost 1,000 children per day worldwide, according to the World Health Organization (WHO). This highlights the serious impact of water pollution on public health and underscores the importance of ensuring access to clean water sources.

II. RELATED WORKS

Some of the recent research works are discussed below

Pasika and Gandla [1] developed a monitoring system utilizing a series of sensors to measure water quality parameters, including turbidity, pH value, water level, ambient humidity, and temperature. These sensors are connected to a microcontroller unit (MCU) which processes the data and communicates with a personal computer (PC) for further analysis. To monitor water quality, the data is transmitted to the cloud via the ThingSpeak Internet of Things (IoT) application. In future work, additional parameters such as nitrates, electrical conductivity, dissolved oxygen, and free residual chlorine should be analyzed. It is recommended that further research be conducted in this area.

Mukta et al. [2] proposed an IoT-based Smart Water Quality Monitoring (SWQM) system that continuously measures water quality parameters such as pH, temperature, turbidity, and electrical conductivity. The system uses four sensors connected to an Arduino Uno to collect data which is then transmitted to a desktop application developed on the .NET platform. The collected data is compared to standard values to determine the water quality. The SWQM model uses a fast forest binary classifier to effectively investigate water quality parameters and classify the water sample as potable or not. As a future direction, the authors suggest expanding the system to include additional sensors to measure other parameters such as dissolved oxygen and free residual chlorine.

Konde and Deosarkar [3] presented a method to design a Smart Water Quality Monitoring (SWQM) system using an IoT environment with a reconfigurable sensor interface. The model includes sensors, a wireless communication module based on Zigbee, and an FPGA board to measure six different water quality parameters such as pH, turbidity, humidity, water level, water temperature, and carbon dioxide (CO2) in real-time. The proposed method aims to monitor and maintain a safe and balanced environment for water bodies, while also reducing costs and time for determining water quality within the framework of environmental and ecological balance management. As a future direction, the authors propose developing a wireless sensor network (WSN) with additional nodes to expand the coverage area. This system has the potential to improve water quality monitoring and management for sustainable water resource management.

Amruta and Satish [4] is a solar-powered wireless sensor network (WSN)-based water quality monitoring system. It consists of an underwater WSN powered by photovoltaic panels, a base station, and distributed sensor nodes for real-time water quality monitoring at various locations. The WSN uses Zigbee technology to connect the nodes and base stations. The system collects data from various sensors measuring parameters like turbidity, oxygen level, and pH values, which are then transmitted to the base station for analysis using simulation tools. The system has several benefits, including lower energy consumption, zero carbon emissions, and more flexibility.

Sughapriya et al. [5] proposed a method to determine water quality using the Internet of Things and various sensor modules. The system utilizes sensors to monitor water quality by measuring pH, turbidity, conductivity, and temperature. The Arduino controller obtains access to the sensor data, which is analyzed using IoT to investigate water pollution through a rigorous mechanism. The system also sends alerts and notifications to concerned individuals and authorities regarding water quality. Monitoring water quality can be achieved with less training, and installation of the system near water sources is effortless. The proposed model consists of various sensors that calculate water quality parameters in real-time, enabling immediate action plans. The model is accurate, economical, and requires less manpower.

Unnikrishna Menon et al. [6] developed a river water quality monitoring method based on wireless sensor networks that allows for continuous and remote monitoring of water quality parameters. The system utilizes a wireless sensor node designed to monitor water pH, a key parameter affecting water quality. The sensor node consists of a processing module, a signal conditioning module, a power supply module, and a wireless communication module, with the sensed data from the pH sensor communicated to the base station using a Zigbee module after necessary signal processing and conditioning. A circuit was developed for the sensor node, with a hardware prototype designed, simulated, and built using appropriate circuit components to minimize the power requirement and provide a low-cost platform for monitoring water quality. This system enables efficient monitoring of water sources and minimizes costs, providing a useful tool for maintaining water quality.

Prasad et al. [7] proposed an intelligent water quality monitoring system in Fiji using remote sensing and Internet of Things (IoT) technology. The system monitors qualitative parameters such as oxidation and reduction potential (ORP) and potential hydrogen (pH) to analyze water quality. The authors aim to develop an early warning system for water pollution using numerous monitoring stations. They conducted a water quality study in the Fiji Islands and compared various parameters such as turbidity, pH, temperature, and conductivity. The system proved effective in providing accurate and reliable values for real-time water monitoring. The authors verified the measurement accuracy of the system by checking four water sources at hourly intervals for 12 hours. They also observed a relationship between temperature and conductivity and pH for samples from all four water sources. The authors implemented GSM technology to send alarms based on reference parameters to the end user for immediate action to ensure water quality. Moreover, they used the reference parameters obtained from all four water sources to build classifiers for automated water analysis through Neural Network Analysis. The developed system is accurate, reliable, and can provide an early warning for water pollution.

Jerome B. et al. [8] proposed an IoT-based Smart Water Quality Monitoring System that utilizes cloud and deep learning methods to monitor water quality in various water resources. The traditional method of manually collecting water samples from different sources and testing them in a laboratory is ineffective and time-consuming, as it does not produce real-time results. To combat environmental issues and improve the quality of life, there is a need for continuous monitoring of water quality using cost-effective real-time monitoring systems. The developed system is based on IoT devices and Node-MCU for continuous monitoring of water quality. The Node-MCU is connected to the internet through a built-in Wi-Fi module, which transfers the sensor data to the cloud. The prototype monitors various contaminants present in water using different sensors to assess water quality parameters. The collected data is stored in the cloud, and deep learning techniques are used to predict whether the tested water is potable or not. This method helps in real-time monitoring of water quality in various water resources using IoT devices, which improves the well-being and quality of life of all living beings.

Geetha and Gouthami [9] presented a simple and cost-effective solution for monitoring pipeline water quality using the Internet of Things. The proposed model is capable of testing water samples and uploading sensor data over the internet for analysis. It comprises a master controller with a built-in Wi-Fi module to monitor various quality parameters such as turbidity, conductivity, and pH. The system also features a warning device to alert users of any deviations in water quality parameters. The implementation enables sensors to transmit data easily over the internet to end users. The experiment's setup can be further enhanced by integrating algorithms for detecting anomalies in water quality.

Sengupta and his team [10] proposed an IoT-based solution for real-time water quality monitoring and control that is cost-effective and efficient. The system comprises various sensors, including temperature, turbidity, and pH sensors, which are connected to a Raspberry Pi via an analog-to-digital converter (ADC). The Raspberry Pi processes the data from the sensors and directs the solenoid valve to either continue or stop the flow of water from the upper tank to the houses using a relay mechanism. This entire process is automated, without requiring any human intervention, thereby saving time. The system also checks if the weather parameters of water quality are within the desired range or not. All the devices used in this system are affordable, flexible, and highly efficient.

III.MATERIALS AND METHODS

Water quality monitoring systems typically consist of various hardware and software components, including:

- Arduino UNO
- LCD Display
- Total Dissolved Solids (TDS)Sensor
- Temperature and Humidity Sensor (DHT11)
- ESP32
- Analog pH Sensor
- Thingspeak Platform

Arduino UNO:

The Arduino UNO is a microcontroller board that is designed to be user-friendly and accessible to those new to electronics and coding. It features 14 digital input/output pins, six of which can be used for pulse-width modulation (PWM), as well as six analog inputs, a 16 MHz ceramic resonator, a USB connection, power jack, ICSP header, and reset button. Its popularity within the Arduino community is due in part to its ease of use and comprehensive documentation. The UNO allows microcontrollers to connect to Wi-Fi networks and establish TCP/IP connections using Hayes-style commands. Despite a lack of initial English-language documentation for the chip and its commands, the UNO contains all necessary information to support the microcontroller. The board can be easily connected to a computer via USB and can be powered using an AC-to-DC adapter or battery. Additionally, the UNO is an affordable option for beginners, as the chip can be replaced at a low cost if experimentation goes awry.

Fig: 1. Arduino UNO

LCD Display:

LCDs are flat panel displays that use liquid crystals in combination with polarizers to modulate light. They do not emit light directly but use a backlight or reflector to produce color or monochrome images. LCD displays can show arbitrary images or fixed images with low information content, such as preset words and numbers. They are used in various applications, including televisions, computer monitors, instrument panels, signage, and consumer electronics such as DVD players and video game consoles.

LCD screens are replacing CRT screens in almost all applications due to their lightweight, wide range of screen sizes, and low power consumption. They are being replaced by OLEDs, which have lower response times, wider color gamut, infinite color contrast, and slimmer profiles. OLEDs are more expensive due to the expensive electroluminescent materials or phosphors they use. Quantum dot displays, marketed as SUHD, QLED, or Triluminos, offer similar performance to OLED displays but are less expensive. However, the quantum dot layer cannot yet be recycled.

LCD screens rarely experience image burn-in, making them ideal for displaying static images for an extended period of time. They are more energy-efficient and can be disposed of more safely than CRTs. By 2008, LCD TV sales had exceeded CRT sales, and CRTs had become obsolete for most purposes. It consists of multiple layers of polarized glass, with a layer of liquid crystal material sandwiched between them. The liquid crystals align themselves in response to an electric current, thereby allowing or blocking the passage of light through the display.

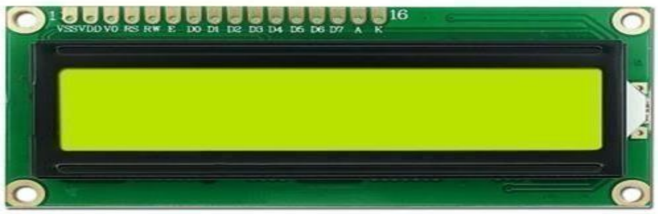

Fig: 2. LCD Display

Total Dissolved Solids (TDS) Sensor:

A TDS meter is a device used to measure the total amount of dissolved solids in water, including salts, minerals, and metals. The conductivity of the water increases as the amount of dissolved solids in the water increases, allowing for the calculation of total dissolved solids in ppm (mg/L).

- A TDS meter is applicable in various scenarios including monitoring water quality in hydroponics, swimming pools, aquariums, water purifiers, and other applications.
- Wide-angle voltage input: 3.3~5.5V.
- It has good compatibility output with a 02.3V analog signal output that is compatible with 5V or 3.3V regulator.
- It utilizes an AC excitation source that prevents probe polarization, making it easy to use.
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A decision tree classifier is a type of classifier that uses a tree-like structure to represent the attributes, decision rules, and results of a dataset. The root node starts the tree and the best attribute is used to split the node into subsets until a leaf node is reached that provides the result. On the other hand, a TDS meter is a portable device used to measure the total dissolved solids in water sources. It measures the TDS level in PPM or mg/L, which both represent the concentration of dissolved solids in water. The conductivity of the solution is measured, and a higher conductivity value indicates a higher TDS level due to the presence of dissolved ionized solids such as minerals and salts. TDS meters are often used in applications such as monitoring water quality in swimming pools, aquariums, hydroponics, and water purifiers.

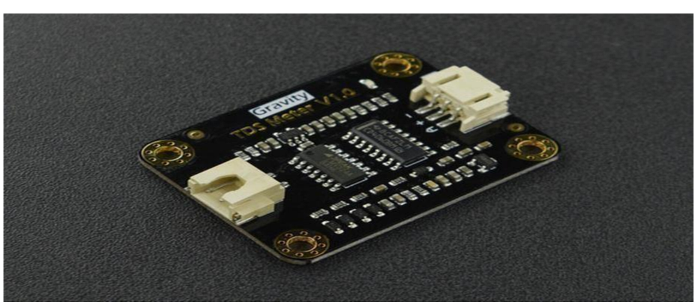

Fig: 3. TDS Sensor

Temperature and Humidity Sensor (DHT 11):

The temperature and humidity sensor (DHT11) is a basic low-cost sensor for detecting the temperature and humidity of a given element. It uses a capacitive humidity sensor and thermistor to measure ambient air or water and spits out a digital signal on the data pin (no analog input pins needed). It's fairly simple to use but requires careful timing toget the data.

The DHT11 temperature and humidity sensor comes with several features,

- Full range temperature compensated.
- Calibrated digital signal.
- Outstanding long-term stability
- No requirement for extra components
- Low power consumption

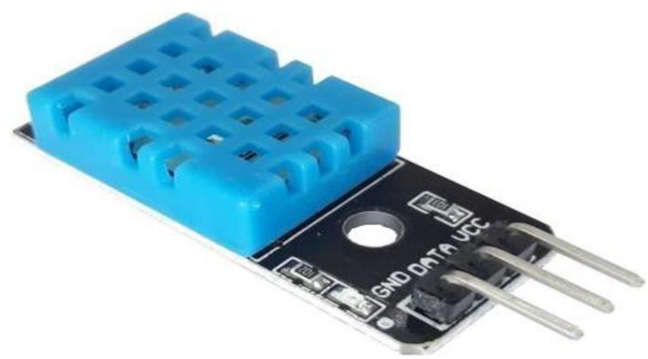

Fig: 4. DHT 11

ESP 32 Module:

The ESP32 is a versatile microcontroller that can function as a standalone system or a slave device to the host MCU, thus reducing communication stack overhead on the primary application processor. It offers Wi-Fi and Bluetooth capabilities via SPI/SDIO or I2C/UART, making it highly compatible with other systems. Additionally, it is an affordable and power-efficient system on chip with built-in Wi-Fi and dual-mode Bluetooth. The ESP32 series utilizes either the Tensilica Xtensa LX6 microprocessor in dual-core or single-core variants, the Xtensa LX7 dual-core microprocessor, or the RISC-V single-core microprocessor. It also features built-in antenna switches, an RF balun, a power amplifier, a low-noise receiver amplifier, filters, and power management modules. The ESP32 was developed by Espressif Systems, a Chinese company based in Shanghai, and is manufactured by TSMC using their 40nm process.

Espressif Systems created the ESP32, an inexpensive and low-power consumption SoC and module. It is the successor to the popular ESP8266, and in addition to built-in Wi-Fi, reduce the contaminants present in the water.

it also supports Bluetooth and Bluetooth Low Energy. The ESP32 is based on a dual-core Tensilica Xtensa LX6 microprocessor with a clock speed of up to 240 MHz and features energy-saving options such as clock synchronization and multiple operating modes, resulting in a quiescent current of less than 5µA. The ESP32 is well-suited for IoT applications and battery-powered projects due to its low power consumption.

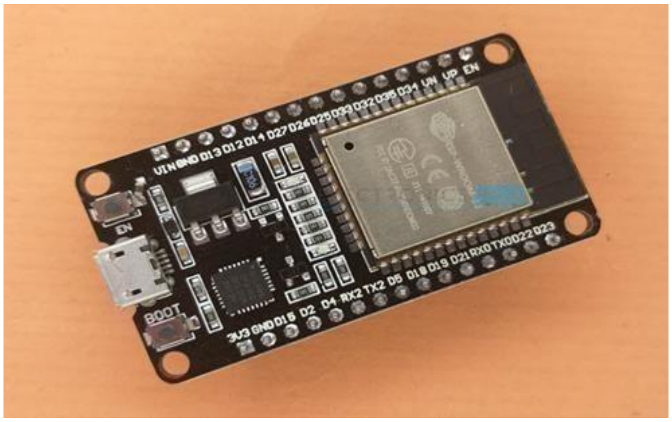

Fig: 5. ESP 32

Analog pH Sensor:

A pH sensor is an instrument that is commonly used in various industries to measure the acidity or alkalinity of liquids, including water. It is a crucial tool for monitoring water quality, as the pH value is a key parameter in determining it. The pH sensor and pH meter work by exchanging ions between the sample solution and the internal solution (pH 7 buffer) of the glass electrode through the glass membrane. Over time, the porosity of the glass membrane may decrease, affecting the probe's performance. When the probe is placed in a solution, hydrogen ions replace metal ions from the flask, creating an electric current that is detected by the silver wire. The pH meter measures the voltage of this electric current and converts it into a pH value by comparing it to a reference electrode. A higher concentration of hydrogen ions leads to a higher voltage and a lower pH reading on the pH meter.

Fig: 6. pH Sensor

ThingSpeak:

ThingSpeak is a versatile open-source platform that supports building IoT applications. It provides a range of services, including real-time data collection, data visualization in the form of graphs, and the creation of plugins and applications for interaction with web services, social networks, and other APIs. The platform also offers integrated support for Math Works' MATLAB software, allowing users to analyze and visualize recorded data using MATLAB without purchasing a MATLAB license. ThingSpeak has been featured in articles on various "Maker" sites, including Instructables, Code project, and Channel. One of the core elements of ThingSpeak is the 'ThingSpeak Channel'. ThingSpeak is a platform that enables users to create and manage channels for storing and processing data collected from IoT devices. A channel in ThingSpeak can store up to 8 data storage fields of any type, making it suitable for storing sensor or device data. Additionally, ThingSpeak channels also support 3 location fields for storing latitude, longitude, and altitude, which can be useful for tracking moving devices. Users can also include a status field in their channels to provide short descriptions of the data stored. To use ThingSpeak, users need to register and create a channel, after which they can send data to ThingSpeak and retrieve it as needed. By signing up and creating a channel, users can begin exploring the many features of ThingSpeak.

In order to measure the TDS level in water, the sensor leads of the TDS meter are immersed in the water to be tested. The TDS sensor values are then processed by the analog-to-digital converter (ADC), and the core controller will read the value and upload it to the cloud for monitoring. The values are continuously monitored by checking if the sensor value is higher than the threshold value or not.

In case the sensor value is above the threshold value, an alert or notification will be sent to the designated end-user for further action. However, if the sensor value is below the threshold value, the system will proceed to check the parameters again for another water source.

The proposed work comprises of two main components: hardware and software. A schematic diagram is presented to illustrate the system architecture.

The system consists of various hardware components, such as sensors that measure values in real-time, an Arduino ATMEGA328 that converts analog values to digital, an LCD display that shows outputs from the sensors, and a Wi-Fi module that establishes a connection between the hardware and software. The ATMEGA328 comes with a built-in ADC and Wi-Fi module. The system checks the water quality parameters one by one and updates them on the cloud server. The values are also displayed on the LCD screen.

Regular transmission of values to users can keep them informed about the water quality, based on the defined scale for each parameter. In case the water quality is deemed unsafe, relevant authorities can take the necessary measures to purify the water, and the community can take steps to

Such measures can increase the overall quality of water, making it safer for use.

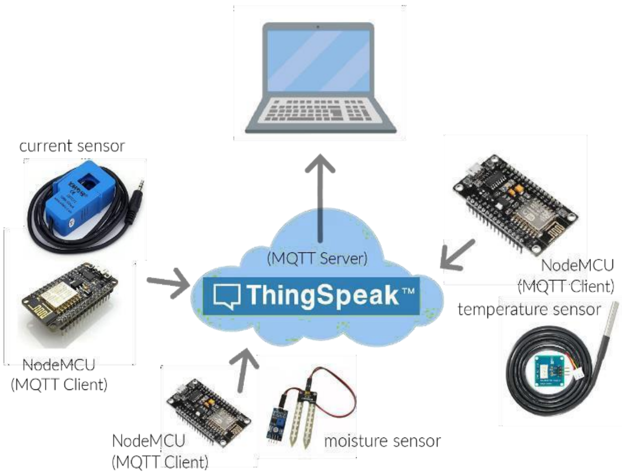

Fig: 7. Overlook of ThingSpeak

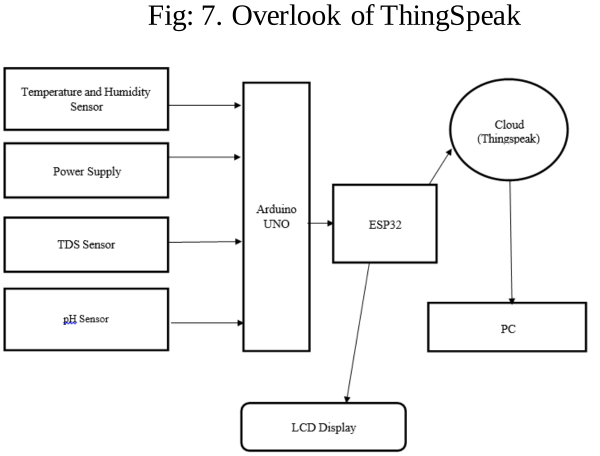

Fig: 8. Block Diagram of Water Quality Monitoring System

IV.RESULT

The use of multiple sensors can lead to a higher number of extracted features, which can result in complex calculations. The system consists of an Arduino board connected to TDS and pH sensors, as well as a DHT11 sensor. Once the microcontroller and sensor setup is complete, the board needs to be connected to a power source. The microcontroller is connected to a PC via USB to display the results and recognized water quality in a sequential format. The program is compiled and transferred to the Arduino board using the Arduino compiler.

This water quality monitoring system is designed to provide information about the state of water in different areas or water bodies. It is user-friendly and can be accessed using an IoT-enabled mobile phone or computer from anywhere in the world. The device only requires a portable battery, which provides a backup of 10 hours.

To demonstrate the quality of water, the pH sensor is placed in a container of tap water with a few drops of acid added. The resulting graphs show that the water is acidic, with a pH level ranging from 3 to 4.5. The surrounding temperature remains between 32 to 34 degrees.

The proposed system is a cost-effective and reusable solution to address the worsening water quality caused by factors such as limited drinking water resources, urbanization in rural areas, and excessive use of sea resources for salt extraction. As future guidelines, the latest sensors and wireless communication standards can be used to improve the water quality monitoring system and ensure the security of water resources with immediate response.

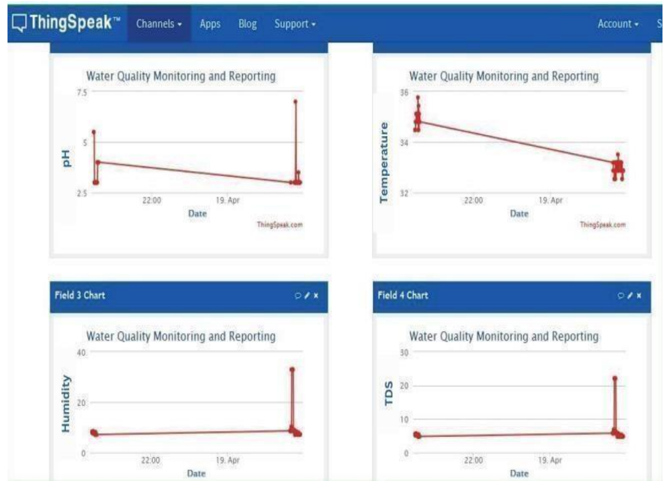

Fig: 9. ThingSpeak Output

V.CONCLUSION

Water pollution is a major threat to any country as it affects health, economy and spoils biodiversity. In this work, the causes and consequences of water pollution are presented, as well as a comprehensive overview of various water quality monitoring methods, and an effective method for monitoring water quality based on the Internet of Things was discussed. Although there are many excellent intelligent water quality monitoring systems, the field of research still remains challenging. This work presents an overview of recent work done by researchers to make water quality monitoring systems intelligent, low energy and high efficiency so that monitoring is continuous and alerts/notifications are sent to relevant authorities for further processing. The developed model is cost effective and easy to use (flexible). Three water samples are tested and based on the results the water can be classified as potable or not. As future guidelines, it is proposed to use the latest sensors to detect various other quality parameters, use wireless communication standards for better communication and IoT to create a better water quality monitoring system and water resources can be secured with immediate response.

VI.REFERENCES

[1] S.Pasika, S.T. Gandla, Smart water quality monitoring system with cost-effective using IoT, Heliyon 6 (7) (2020), doi:10.1016/j.heliyon.2020.e04096.

[2] M.Mukta, S. Islam, S.D. Barman, A.W. Reza,M.S. Hossain Khan, "Iot based smart water quality monitoring system, in:Proceedings of the IEEE 4th International Conference on Computer and Communication Systems (ICCCS), 2019, pp. 669-673,doi:10.1109/CCOMS.2019.8821742.

[3] S. Konde, S. Deosarkar, IOT based water quality monitoring system, in: Proceedings of the 2nd International Conference on Communication & Information Processing (ICCIP), 2020 2020, doi: 10.2139/ssrn.3645467.

[4] Solarmonitoring system using wireless sensor network, in: Proceedings of the International Multi-conference on Automation, Computing, Communication, Control, Compressed Sensing(iMac4s),2013,pp.281-285, doi:10.1109/iMac4s.2013.6526423

[5] T.Sugapriya, S. Rakshaya, K. Ramayadevi, M. Ramya, real time applications, Int. J. Pure Appl. Math. 118(2018) 1363- 1369.

[6] K.A. Unnikrishna Menon, D. P., M.V. Ramesh, Wireless sensor network for river water quality monitoring in India,in: Proceedings of the Third International Conference on Computing, Communication and Networking Technologies (ICCCNT'12), 2012,

[7] A.N. Prasad, K.A. Mamun, F.R. Islam, H. Haqva, Smart quality monitoring system , in: Proceedings of the 2nd Asia- Pacific World Congress on Computer Science and Engineering (APWC on CSE), 2015, pp. 1-6, doi:10.1109/AP- WCCSE.2015.7476234.

[8] jerom B., R. Manimegalai, R. Manimegalai, An IoT based smart water quality monitoring system using cloud, in: Proceedings of the International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE), 2020, pp. 1-7, doi:10.1109/ic-ETITE47903.2020.450. 2020.

[9] S.Geetha, S. Gouthami, Internet of things enabled real time water quality monitoring system, Smart Water 2 (1) (2016), doi:10.1186/s40713-017-0005-y.

[10] B. Sengupta, S.Sawant, M. Dhanawade, S. Bhosale, water quality monitoring system in IoT, Int. Res. J. Eng. Technol. 6 (2019) 695-701.

[11] S.Konde, S.Deosarkar, IoT based water quality monitoring system, in:Proceedings of the 2nd International Conference on Communication &InformationProcessing(ICCIP),2020,doi:10.2139 /ssrn.3645467.

[12] Pallavi Sethi and Smruti R. Sarangi, IIT Delhi, "Internet of Things: architectures, protocols, and applications", Journal of Electrical and Computer Engineering, Article ID 9324035, 25 pages, 2017.

[13] Ahmed Khalid, "Smart applications for smart live", IJCSMC, Vol. 5, Issue. 10, pg.97 – 103, October 2016.

[14] Jun Zheng, Southeast University, China, Abbas Jamalipour, University of Sydney, Australia, " Introduction to wireless sensor networks ", IEEE 2009.

[15] Augustine Ikpehai, Bamidele Adebisi, Khaled M. Rabie, Kelvin Anoh, Ruth E. Ande, Mohammad Hammoudeh, and Uche M. Mbanaso, Members IEEE,2018.

[16] Ashraf A. Taha, Mohamed F. Feteiha and Wadood Abdul,"Performance evaluation for LoRa transceiver ", International Journal of Computer Science and Software Engineering (IJCSSE), Volume 8, Issue 2, February 2019.

[17] A. P. U. Siahaan, nogar silitonga, muhammad iqbal, solly aryza, wirda fitriani, Zuhri ramadhan, rahmad hidayat, h, " Arduino Uno-based water turbidity meter using LDR and LED sensors ", International Journal of Engineering & Technology, 2018.

[18] Usman Raza, Parag Kulkarni, and Mahesh Sooriyabandara, "Low power wide area networks: an overview", ieee communications surveys & tutorials, volume: 19 , issue: 2, jan 2017.

[19] Alexandru Lavric, Valentin Popa, "Internet of things and LoRa lowpower widearea networks challenges", ieee 2017 9th international conference on electronics, computers and artificial intelligence (ecai).

[20] Bo Sun, Fengchao Zhu, Wenjuan Zhang, "Connect wireless sensor network with internet through cloud gateway", ieee 2015, 11th international computer conference on wavelet actiev media technology and information processing (iccwamtip).

[21] Faheem Zafari, Athanasios Gkelias, Kin K. Leung, ieee members, "A survey of indoor localization systems and technologies", arxiv:1709.01015v3 [cs.ni] 16 jan 2019.

[22] Sittikorn Muekdang and Wimol San-Um, "Intelligent rf-based indoor localization through rssi of lora communication technology", International journal of future computer and communication, vol. 7, no. 4, december 2018.

[23] Kamil Staniec and Michał Kowal, “Lora performance under variable interference and heavy-multipath conditions”, Wireless communications and mobile computing volume 2018,

[24] A.T. Demetillo, M.V. Japitana, E.B. Taboada, A system for monitoring water qualityin a large aquatic area using wireless sensor network technology, Sustain. Environ.Res. 29 (2019) 12, doi:10.1186/s42834-019-0009-4.

[25] L. Zhen, A.K. Bashir, K. Yu, Y.D. Al-Otaibi, C.H. Foh, P. Xiao, Energy-efficient randomaccess for LEO satellite-assisted 6G internet of remote things, IEEE Internet ThingsJ. (2021), doi:10.1109/JIOT.2020.3030856.

[26] S.A. Hamid, A.M.A. Rahim, S.Y. Fadhlullah, S. Abdullah,Z. Muhammad, N.A.M. Leh,IoT based water quality monitoring system and evaluation, in: Proceedings of the10th IEEE International Conference on Control System, Computing and Engineering (ICCSCE), 2020, pp. 102–106, doi:10.1109/ICCSCE50387.2020.9204931. 2020.

[27] S. Gupta, M. Kohli, R. Kumar, S. Bandral, IoT based underwater robot for water quality monitoring, IOP Conf. Ser. Mater. Sci. Eng. 1033 (2021) 012013, doi:10.1088/1757- 899x/1033/1/012013.

[28] C. Puttamadappa , B.D. Parameshachari , Demand side management of small scale loads in a smart grid using glow- worm swarm optimization technique, Microprocess. Microsyst. 71 (2019) 102886 .

[29] P.N. Hiremath , J. Armentrout , S. Vu , T.N. Nguyen , Q.T. Minh , P.H. Phung , MyWeb- Guard: toward a user-oriented tool for security and privacy protection on the web, in: Proceedings of the International Conference on Future Data and Security Engineering, Springer, 2019, pp. 506–525. Cham .

[30] D.L. Vu , T.K. Nguyen , T.V. Nguyen , T.N. Nguyen ,F.Massacci , P.H. Phung , A con- volutional transformation network for malware classification, in: Proceedings of the 6th NAFOSTED conference on information and computer science (NICS) IEEE, 2019, pp. 234–239 .