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Development of Cloud-based Water Quality Monitoring System

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***Abstract*-- Water quality is paramount for sustaining life and maintaining ecological balance. However, traditional monitoring methods often must improve by providing real-time and comprehensive information. The developed systems show a cloud-based water quality monitoring system that overcomes the drawbacks of conventional approaches. The system allows numerous users to collect, store, and retrieve real-time data by combining sensors, an ESP32 microcontroller, Google Firebase Cloud, and a mobile application. The prototype illustrates the viability of using cloud computing to monitor water quality accurately and thoroughly. This effort advances the field by highlighting water quality is importance to supporting ecosystems and life. It highlights the system's contribution to allowing proactive decision-making and quick solutions to water quality challenges while outlining potential directions for future advancements in sensor calibration, testing in various water bodies, and cutting-edge data analytics methods. The cloud-based system for monitoring water quality has uses in various fields, such as environmental management, public health, and water resource conservation. It makes it easier to make educated decisions and take preventative action to preserve water quality and sustainability.**

Keywords: Cloud-based services, public health, water quality.

I. Introduction

This chapter sets the foundation of the thesis stressing the importance of the water quality monitoring system in Pakistan and the demand for a creative solution. It highlights the project's goals, which include creating a user-friendly mobile app and a cloud-based system for monitoring water quality utilizing sensors and an ESP 32 module. The chapter also emphasizes how the system may enhance Pakistan's public health protection, early contamination detection, and water management methods.

A. Problem Statement:

Manual sampling is labor intensive, time consuming, and frequently produces data. On the other hand, laboratory analysis requires special equipment, Restrictions make it difficult to identify sources of pollution and monitor water quality.

B. Motivation:

The potential influence this initiative could have on resource management, environmental cloud-based water quality monitoring system using the ESP 32 module with sensors for plans into action, and improve methods for managing water resources. potential to improve environmental sustainability, safeguard public health, and help ensure.

II. Parameters Used for Monitoring Water Quality

The system uses sensors for turbidity, temperature, pH, and TDs to measure the important aspects of water quality.

A. Turbidity:

The turbidity sensor employed in this project determines the degree of cloudiness or water quality and probable degrees of contamination. This knowledge is essential for spotting potential dangers and implementing effective water treatment procedures.[2].

B. Temperature

Since temperature fluctuations can substantially impact aquatic ecosystems and water quality measures, the temperature sensor is essential for monitoring water quality. To identify temperature variations that might impact the water's dissolved oxygen levels, biological activity, and chemical processes, it detects the thermal conditions of the water.[3] Monitoring water temperature helps determine thermal pollution, understand the effects of temperature changes on aquatic life, and get insights on the general health of the water body.

C. Potential of Hydrogen (PH):

The project's pH sensor determines if water is acidic or alkaline. Since pH affects chemical balance, the solubility of minerals, and the growth and survival of aquatic species, it is a crucial criterion in the evaluation of water quality. The sensor helps detect possible problems like acidification or alkalization of water, which can have negative consequences on aquatic life and water use, by keeping track of pH values [4]. The appropriateness of water for many applications, such as drinking water, irrigation, and industrial processes, depends on accurate pH measurements.

D. *Total Dissolved Solids (TDs):*

The TDS sensor measures the concentration of dissolved solids in water, such as minerals, salts, metals, and other organic and inorganic substances [5]. It is crucial to monitor TDS levels to determine the purity of water and its suitability for various uses. Increased TDS levels can indicate pollution, an overabundance of minerals, or contaminants in water sources. The sensor assists in identifying possible problems with water quality and facilitates the implementation of effective treatment procedures by monitoring TDS concentrations. It offers useful data for managing water resources, assuring the supply of safe, high-quality water for various uses.

III. LITERATURE REVIEW

The quality of the water supply is a crucial indicator of environmental pollution and how it impacts humans in general. Water contamination might occur intentionally or accidentally, resulting in severe consequences if fast action is not taken. This literature study assesses the practicality of several systems for real-time water quality monitoring, focusing on those tested out in actual circumstances.

A. *Sensor Nodes and Communication:*

R. Karthik Kumar [6] presents a thorough investigation of implementing a WSN system for water quality monitoring. The system's sensor nodes are directly powered, guaranteeing continuous operation and eliminating the need for regular battery changes. For data connection, these sensor nodes use Wi-Fi and Bluetooth technologies. They have sensors that assess several factors, including pH, oxygen levels, and turbidity, and they are dispersed strategically around the monitoring area. Using Wi-Fi or Bluetooth connection protocols, the gathered data is sent to a central base station. The data received is stored and processed by this base station, which also serves as a data aggregator. Additionally, the data may be uploaded to the cloud, where interested parties in managing water resources can access and analyze it (see Fig. 1).

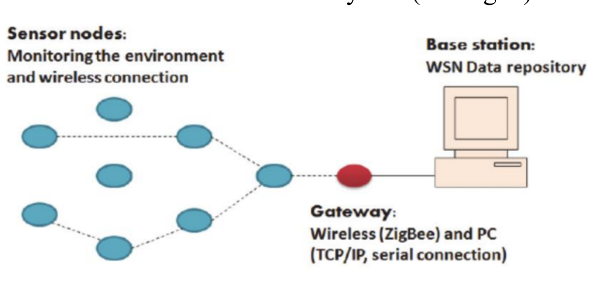

Figure 1. A wireless sensor network

B. *Reliable Data Transmission:*

P. Jiang et al. [7] propose a Link Quality Estimation based Routing (LQER) protocol to provide trustworthy data delivery in applications for monitoring the aquatic environment. Both link quality and energy efficiency are priorities for the protocol. It chooses the best path for data transfer, considering signal quality and dependability. The protocol increases the overall effectiveness of data transfer by utilizing Bluetooth and Wi-Fi technologies, which lowers the likelihood of packet loss or retransmission. By reducing pointless retransmissions, this strategy improves the monitoring system's dependability while simultaneously saving energy. The information gathered by the sensor nodes is then sent to the cloud, where it may be safely kept and accessible for additional research and decision-making.

C. *Monitoring Industrial Sewage Contamination:*

Akila. U et al. [8] propose a computerized wireless gadget to monitor sewage-contaminated industrial water quality. The system measures several factors important for determining water quality using a variety of sensors, including pH probes and temperature sensors. These sensors gather analogue data, which is then transformed into digital values by an Arduino board. After that, the digital data is contrasted with predetermined threshold values. An automatic warning message is delivered to the Pollution Control Board through cloud communication if the pollution level exceeds the set limits. This enables quick response and prompt intervention in industrial sewage pollution incidents. The cloud-based connection allows for smooth and effective warning message transmission, permitting quick action from the relevant authorities. Additionally, by archiving the gathered data in the cloud, it is possible to analyze long-term trends and patterns to create proactive industrial wastewater management strategies.

D. *Remote Sensor System for Water Quality:*

Feng Zhang et al. [9] introduce the Smart Coast system, a remote sensor system for water quality monitoring. The system uses a "plug and play" sensor platform, inexpensive sensors, and effective Wi-Fi and Bluetooth communication to build a complete and flexible monitoring solution. Sensors for detecting variables including pH, temperature, conductivity, turbidity, and depth are integrated into the Smart Coast system. To prevent water damage, these sensors are securely housed in watertight casings. Utilizing Wi-Fi or Bluetooth, the acquired data is wirelessly transported to a central base station, which may be further communicated and stored in the cloud for analysis and access. This cloud-based method allows for remote water quality monitoring, prompt water resource management and real-time decision-making (see Fig. 2).

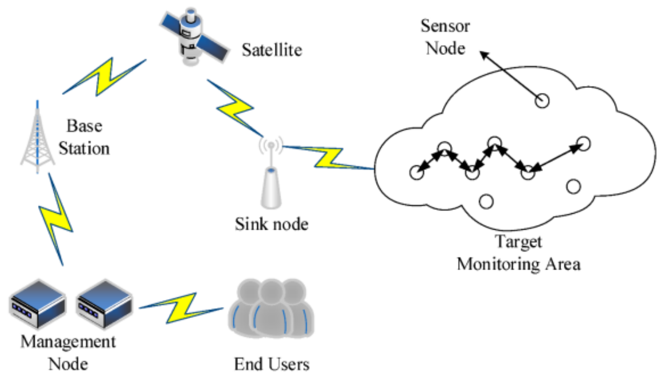

Figure. 2. Remote Sensor System

E. Wireless Sensor Networks and Applications:

I.F. Akyildiz et al. [10] provide an overview of wireless sensor networks (WSNs) and their applications in various fields. WSNs comprise many sensor nodes placed in a sensor field to gather and send data to a base station or central sink. These networks have distinctive qualities, including self-organization and collaboration amongst sensor nodes. Widespread usage of WSNs has been observed in several fields, including surveillance, military leadership, intelligence, and health monitoring. WSNs make it possible to deploy sensor nodes over a monitoring region in the context of water quality monitoring, guaranteeing comprehensive coverage and data collecting. The sent and stored data from sensor nodes may be used for remote access, analysis, and monitoring of water quality indicators. Water quality monitoring systems are more scalable, effective, and accessible when WSNs and cloud computing are combined.

F. Multi-sensor Devices:

It's important to remember that multi-sensor devices can do tasks like bioassays. The toxicity of contaminated water samples was assessed in Catalonia (Spain) research using a conventional bioassay approach and a potentiometric multi-sensor system composed of 23 cross-sensitive electrodes [14]. Fifty-four samples, including genuine wastewater samples from various places and a set of model aqueous solutions containing dangerous compounds, were used for the measurements. The bioassay test findings (expressed as EC50, the concentration of the material producing a 50% reduction in luminescence) were utilized as the dependent variable (Y-variable) in the analysis of the generated dataset using various regression techniques. The regression models underwent complete cross-validation and random test set selection for validation. The study showed that the suggested approach could assess the general toxicity of water with EC50 prediction errors of 20% to 25%. Unlike bioassay methods, the suggested sensor array may be used online, making it a useful tool for monitoring industrial water quality.

G. Challenges in Smart Water Management:

In research done in 2021 by Patgar and Patel, Predictive Analysis of Intelligent Sensing and Cloud-Based Integrated Water Management Systems was examined and put into practice [17]. Intelligent water management systems must have efficient quality monitoring, control, distribution, and optimization of usage. However, wise water management poses a special set of difficulties in a nation like India, where the people frequently believe that water supplies are infinitely available. Electricity produced using water-based systems needs a solid metering infrastructure, which results in a flat-rate billing system that does not consider the variable amounts of water usage across homes, in contrast to renewable energy sources like wind and solar power. The authors introduce real-time monitoring of water consumption, leakage detection, the capability to regulate water supply in the event of leaks, and an automated billing system specifically designed for communities and apartment buildings as part of their comprehensive proposal in this chapter to address these issues. Installing flow sensor meters in the primary water inflow pipe is the suggested method, which makes it possible to get precise consumption data. Then, Wi-Fi networks are used to send this data to iOS and Android-compatible applications [17-25].

IV. EXPERIMENTAL WORK

Monitoring water quality is essential for guaranteeing the security and sustainability of water supplies (see Fig. 3). Traditional monitoring techniques have drawbacks regarding cooperation, distant administration, and access to real-time data. Cloud-based water quality monitoring technologies have come to light as a possible response to these issues in recent years [18]. Real-time monitoring, remote data access, and collaborative features are just a few of the quality of the water in real time, enabling quick reactions and interventions [30-38]. no longer a requirement for physical access to monitoring stations thanks to remote data. Large amounts of water quality data are stored, processed, and analyzed by cloud-based water quality monitoring systems [18] utilizing cloud computing capabilities—indicators by fusing sensor technologies with cloud-based platforms. TDS, turbidity, and pH sensors detect and monitor water quality indicators [21] [28, 38-45].

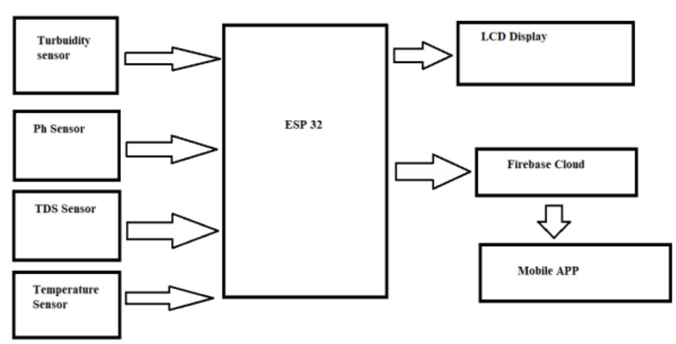

Figure.3: Block Diagram of Cloud-based Water Quality Monitoring System

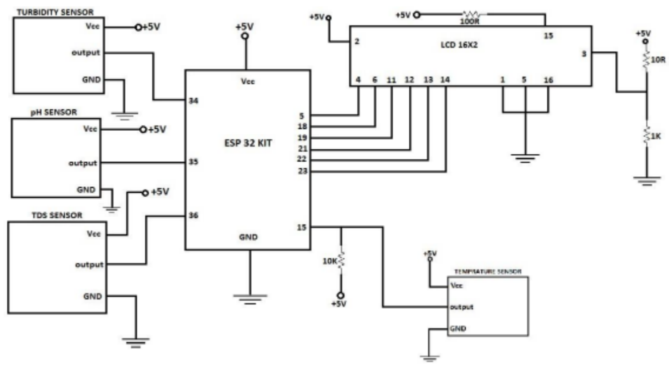

Figure. 4. Circuit Diagram of Cloud-based Water Quality Monitoring System

A. Sensor Technologies:

A cloud-based water quality monitoring system relies heavily on sensor technologies since they make detecting various characteristics that determine the water's quality possible (see Fig. 4). Several sensors, including:

1. A temperature sensor [32]
2. A TDS (Total Dissolved Solids) sensor [33]
3. A turbidity sensor [34]
4. A PH sensor [35]

B. Temperature Sensor:

The prototype`s temperature sensor delivers on-the-spot readings of the water The sensor utilized in this prototype is DS18B20 digital temperature sensor. Because of its precision and ease of use, the DS18B20 digital temperature sensor from simple integration of several sensors with a single data line in Fig. 5.

Figure 5. DS18B20 Temperature Sensor

C. TDS Sensor:

A TDS sensor was integrated into the prototype to measure the concentration of Total Dissolved Solids (TDS) in water. Minerals, salts, and other dissolved solids are measured using TDS sensors, which are used to analyze water. This measurement is crucial for determining whether water suits numerous applications, including drinking, farming, and industry [36]. The TDS sensor employed in this prototype is based on the concepts of conductivity measurement, using electrodes to detect the electrical conductivity of water, which corresponds with TDS levels in Fig. 6.

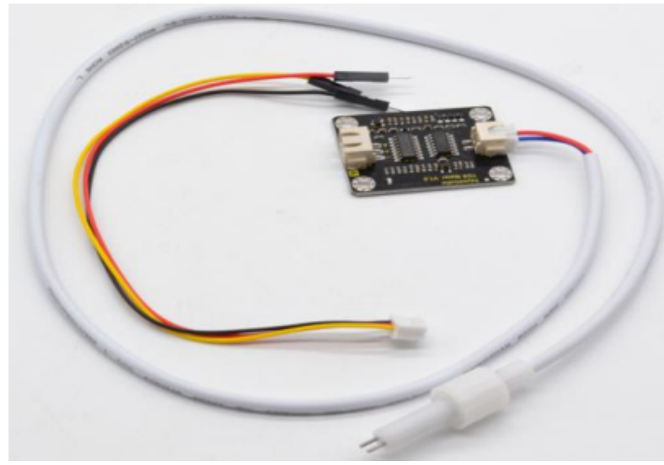

Figure 6. KS0429 TDS Sensor

D. Turbidity Sensor:

Another crucial element of the prototype that allows for measuring water quality is the turbidity sensor in Fig. 7. Turbidity measures water's cloudiness or haziness from suspended particles like silt, organic matter, or contaminants. High turbidity levels can impact water treatment procedures, aquatic life, and light transmission [38]. To quantify the scattering or absorption of light by water particles, the turbidity sensor in this prototype used optical measuring principles, such as infrared or laser-based techniques [46-51].

Figure 7. Turbidity Sensor

E. Ph Sensor:

A pH sensor was included inside the prototype to determine if the water was acidic or alkaline in Fig. 8. PH is a crucial measure of the chemical equilibrium of the water and its possible effects on aquatic ecosystems and human health. The lifespan of aquatic creatures and the chemicals' solubility can be affected by pH values [39]. The hydrogen ion concentration was detected, and pH values were provided by the prototype's pH sensor, which may have been based on pH electrodes or pH-sensitive materials [52-55].

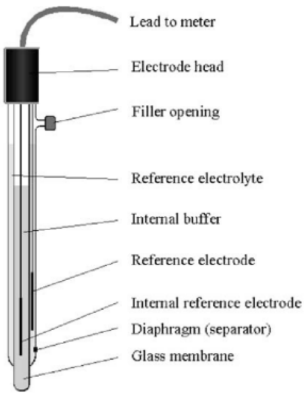

Figure 8. Structural Diagram of PH Electrode

F. ESP 32 WRoom kit:

A powerful, all-purpose Wi-Fi + Bluetooth® module, the ESP32-WROOM-32 performs various tasks, including voice encoding, music streaming, MP3 decoding, and low-power sensor networks in Fig. 9.

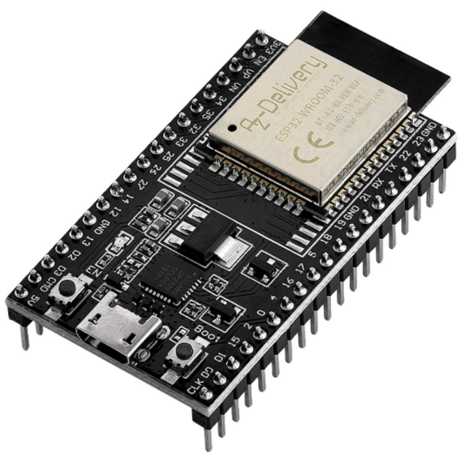

Figure 9. ESP32 module

G. Cloud Infrastructure:

To allow real-time data synchronization in cloud-based water quality monitoring systems, Google Firebase Cloud offers the Firebase Realtime Database, a NoSQL database. The most recent data may be accessed from a variety of devices thanks to its seamless data updates and retrieval capabilities [43].

H. Firebase Authentication and Authorization:

For user administration, Firebase Cloud has built-in capabilities for authentication and authorization. This function enables system administrators to manage user access, protecting the confidentiality and security of data [43]. The integrity and confidentiality of the data gathered can be protected by using user authentication to prevent unauthorized access to the monitoring system and data.

I. Cloud Functions and Messaging:

Developers may perform serverless operations and deliver push alerts to users using Firebase Cloud, which offers cloud functions and messaging capabilities [43]. The responsiveness and usability of the monitoring system may be improved by using these capabilities to provide real-time alerts or messages to users depending on certain water quality thresholds or occurrences in Fig. 10.

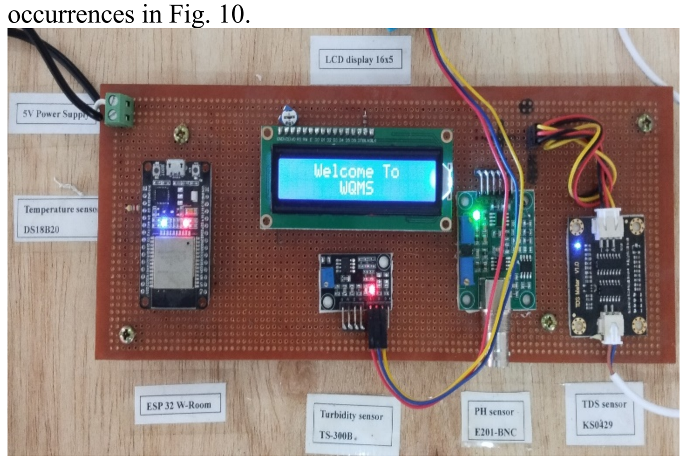

Figure 10. Cloud-based Water Quality Monitoring System in Working State

J. Scalability and Reliability:

Scalability and dependability are two qualities of Firebase Cloud. It can manage enormous amounts of data and user requests, guaranteeing that the system can meet upcoming growth or increasing monitoring needs. This scalability enables the system to efficiently manage expanding datasets and user traffic.

K. User-Friendly Interface and Development Tools:

A simple way to integrate apps with the cloud infrastructure is made possible by Firebase Cloud's user-friendly interface, extensive range of development tools, and APIs [43]. The interface makes it easier for developers to build water quality monitoring capabilities rather than deal with cloud infrastructure management. Table 1 displays the testing of different samples.

Reading	**pH**	**Turbidity (NTU)**	**TDS (ppm)**	**Temperature (°C)**
1	7.2	12	350	25.5
2	6.8	8	420	22.8
3	7.5	18	310	26.2
4	6.5	15	380	23.9
5	8.5	0	400.5	28.1

Table 1: Testing of Different Samples

L. Mobile Application:

The mobile application is essential to your cloud-based water quality monitoring system since it gives users an easy-to-use interface for real-time data access, parameter visualization, and alarm or notification delivery. As a platform for creating the mobile application in your prototype, you choose MIT App Inventor. By using a drag-and-drop user interface and programming language based on blocks, MIT App Inventor is a visual development environment that makes the process of developing Android applications easier. It enables users to create useful and engaging mobile applications even without any programming skills in Fig. 11.

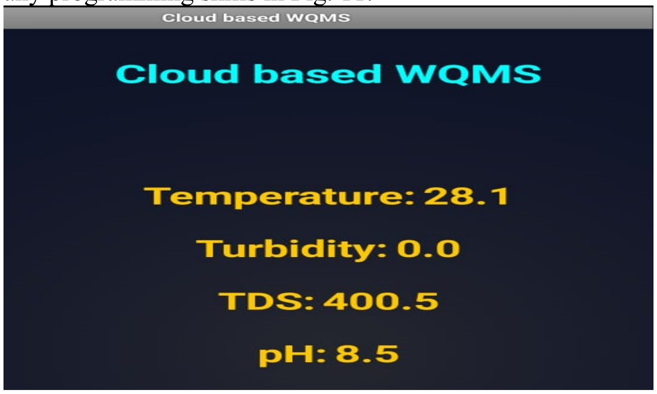

Figure 11. Cloud Accessed Data on Mobile Application

M. User Authentication and Access Control:

Firebase Authentication, which offers user authentication and access control, may be integrated with MIT App Inventor. Users may set up accounts and securely log in to the program, ensuring that only authorized users can access the data on the quality of the water. [49] asserts that MIT App Inventor makes mobile application creation accessible to anyone with little programming skills by streamlining the process. This fits to develop an application for users without a deep understanding of technology. The mobile application's integration of Firebase Authentication for user authentication and access control complies with recommended practices for developing mobile apps [50]. It makes the application more secure and guarantees that only users with permission may access the information about the water quality.

V. CONCLUSION

The prototype of the proposed cloud-based water quality monitoring system shows tremendous promise for tackling water quality monitoring issues. The system combines a Google Firebase Cloud, an ESP32 microcontroller, several sensors, and an MIT App Inventor mobile app to provide real-time monitoring, remote access, and group data analysis. The microcontroller makes data transfer easier, while sensors deliver precise readings of important factors. The mobile app provides simple data visualization, while the Firebase Cloud guarantees safe data storage and user administration. The scalability of the technology enables remote administration and proactive monitoring. It can potentially improve accuracy and functionality using cutting-edge sensors and IoT integration.

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REFERENCES

[1] Bashir, S., Aslam, Z., Niazi, N.K., Khan, M.I., Chen, Z. (2021). Impacts of Water Quality on Human Health in Pakistan. In: Watto, M.A., Mitchell, M., Bashir, S. (eds) Water Resources of Pakistan. World Water Resources, vol 9. Springer, Cham. https://doi.org/10.1007/978-3-030-65679-9_12

[2] YSI, "Turbidity measurement and monitoring in water quality analysis | YSI," www.ysi.com. https://www.ysi.com/parameters/turbidity

[3] Fondriest, "Water Temperature – Environmental Measurement Systems,"EnvironmentalMeasurem[1]Fondriest, "Water Temperature - Environmental Measurement Systems," Environmental Measurement Systems,2014. https://www.fondriest.com/environmental-measurements/parameters/waterquality/water-temperature/ent

[4] Fondriest Environmental, "pH of Water - Environmental Measurement Systems," Environmental Measurement Systems, Nov. 19, 2013. https://www.fondriest.com [1]Fondriest Environmental, "pH of Water - Environmental Measurement Systems," Environmental Measurement Systems,Nov. 19, 2013. https://www.fondriest.com/environmentalmeasurements/parameters/waterquality/ph/environmentalmeasurements/parameters/water-quality/ph/

[5] J. Woodard, "What is TDS in Water & Why Should You Measure It?," Fresh Water Systems, Jul. 17, 2019. https://www.freshwatersystems.com/blogs/blog/what-istds-in-water-why-should-you-measure-it

[6] R.K. Kumar et al. "Solar based advanced water quality monitoring system using wireless sensor network", International Journal of Sciences, Engineering and Technology Research (IJSETR), volume 3, issue 3, march 2014, pp. 385-389.

[7] Peng Jiang, et al. "Research on Wireless Sensor Networks Routing Protocol for Wetland Water Environment Monitoring," Institute of information and control,Hungzhuo Dianzi University.

[8] K. Langendoen, A. Baggio, and O. Visser. Murphy, "Experiences from a pilot sensor network deployment in precision agriculture". Workshop on Parallel and Distributed Real Time Systems (WPDRTS, 2006).

[9] B. O'Flynn, R. Martinez, J. Cleary, "SmartCoast: A Wireless Sensor Network for Water Quality Monitoring," Second IEEE International Workshop on Practical Issues in Building Sensor Network Applications (SenseApp 2007) 15th 18th October 2007 Dublin, Ireland.

[10] I.F. Akyildiz et al, "A Survey on Sensor Networks," Journal. IEEE communication Magazine, August 2002, pp. 102-114.

[11] Yaroshenko et al., "Real-Time Water Quality Monitoring with Chemical Sensors," Sensors, vol. 20, no. 12, p. 3432, Jun. 2020, doi: https://doi.org/10.3390/s20123432.

[12] International Organization for Standardization. Water Quality—Fresh Water Algal Growth Inhibition Test with Scenedesmus Subspicatus and Selenastrum Capricornutum, ISO 8692; International Organization for Standardization: Geneva, Switzerland, 1989; p. 12.

[13] International Organization for Standardization. Water Quality—Determination of The Inhibitory Effect of Water Samples on The Light Emission of Vibrio Fischeri (Luminescent bacteria test). ISO 11348-3; International Organization for Standardization: Geneva, Switzerland, 1998; p. 13.

[14] Zadorozhnaya, O.; Kirsanov, D.; Buzhinsky, I.; Tsarev, F.; Abramova, N.; Bratov, A.; Muñoz, F.J.; Ribó, J.; Bori, J.; Riva, M.C.; et al. Water pollution monitoring by an artificial sensory system performing in terms of Vibrio fischeri bacteria. Sens. Actuators. B Chem. 2015, 207, 1069–1075.

[15] Sawsan Alshattnawi, "Smart Water Distribution Management System Architecture Based on Internet of Things and Cloud Computing," IEEE, Oct. 2017, doi:https://doi.org/10.1109/ictcs.2017.31.

[16] G. Suciu, L. Bezdedeanu, A. Vasilescu, and V. Suciu, "Unified Intelligent Water Management Using Cyberinfrastructures Based on Cloud Computing and IoT,"IEEE Xplore, May 01, 2017. https://ieeexplore.ieee.org/abstract/document/7968620

[17] T. P. Patgar and R. Patel, "Predictive Analysis of Intelligent Sensing and Cloud-Based Integrated Water Management System," IEEE, pp. 247–264, Apr. 2021, doi:https://doi.org/10.1002/9781119740780.ch11.

[18] S. Chen et al., "A cloud-based cyber-physical system for real-time water quality monitoring in fishpond," IEEE Transactions on Industrial Informatics, vol. 13, no.3, pp. 1364-1373, 2017.
[19] N. M. Dang et al., "Cloud-based system for monitoring water quality in smart agriculture," in Proc. 5th Int. Conf. on Computer and Communication Systems, pp.279-283, IEEE, 2021.
[20] N. Khalili-Mahani et al., "Wireless and cloud-based platforms for water quality monitoring: A review," J. of Environmental Management, vol. 256, p. 109978,2020.
[21] B. Li et al., "Internet of things-based water quality monitoring system for aquaculture," in Proc. 37th Chinese Control Conf., pp. 5531-5535, IEEE, 2018.
[22] X. Li et al., "Cloud-based smart system for water quality monitoring," in Proc. 2020 2nd Int. Conf. on Control and Robots (ICCR 2020), pp. 468-472, Atlantis Press, 2020.
[23] X. Li et al., "IoT-based water quality monitoring system using edge computing and big data," in Proc. 2019 10th Int. Conf. on Intelligent Systems and Knowledge Engineering (ISKE), pp. 726-731, IEEE, 2019.
[24] A. Rajabzadeh et al., "Intelligent cloud-based system for water quality monitoring," J. of Hydroinformatics, vol. 23, no. 4, pp. 974-990, 2021.
[25] J. Smith et al., "Cloud-based real-time water quality monitoring system," Procedia Computer Science, vol. 176, pp. 376-383, 2020.
[26] Y. Sun et al., "Cloud-based water quality monitoring and early warning system for urban rivers," IOP Conf. Series: Earth and Environmental Science, vol. 516, no. 2, p. 022102, 2020.
[27] Y. Wang et al., "Design and implementation of a cloud-based intelligent monitoring and analysis system for water quality," Int. J. of Environmental Research and Public Health, vol. 19, no. 2, p. 356, 2022.
[28] S. Wu et al., "A cloud-based monitoring system for water quality management using IoT technology," J. of Sensors, vol. 2019, p. 4854742, 2019.
[29] Y. Xiao et al., "Cloud-based monitoring system for water quality in fishpond," in Proc. 2018 Chinese Control and Decision Conf. (CCDC), pp. 3490-3493, IEEE, 2018.
[30] Z. Zhang et al., "Design of a cloud-based water quality monitoring system," in Proc. 2019 7th Int. Conf. on Smart Energy Grid Engineering (SEGE), pp. 1-5, IEEE, 2019.\
[31] "DS18B20 Programmable Resolution 1-Wire Digital Thermometer," Maxim Integrated. https://www.maximintegrated.com/en/products/sensors/DS18B20.html.
[32] 32. M. Cooper, N. D. Wagner and D. M. Sharpe, "pH sensing in water: advances and future directions," Analytical Chemistry, vol. 91, no. 8, pp. 5057-5068, Apr. 2019.
[33] F. C. Martins, F. C. Faria and J. B. Silva, "Water temperature influence in hydrological regimes of regulated rivers," Journal of Hydrology: Regional Studies, vol. 15, pp. 170-187, Dec. 2017.
[34] G. S. Bilotta, M. Grove and A. S. Gregory, "A state-of-the-art review of the concepts and impacts of 'natural' and 'artificial' particulate matter in the aquatic environment," Water Research, vol. 124, pp. 448-466, Sep. 2017.
[35] V. K. Saxena, V. V. Krishnamurthy and N. C. Gupta, "Quality of water and its relation with human health in the urban and industrial areas of India," Environmental Monitoring and Assessment, vol. 190, no. 2, p. 98, Jan. 2018.
[36] Adafruit Industries, "DS18B20 digital temperature sensor," Adafruit Industries.https://www.adafruit.com/product/374.
[37] Analog Devices, "LM35," Analog Devices. https://www.analog.com/en/products/lm35.html.
[38] mega Engineering, "Conductivity Sensors," Omega Engineering. https://www.omega.com/en-us/sensors-and-sensing equipment/sensors/conductivity-sensors/.
[39] Kashif, Hasnain, Muhammad Nasir Khan, and Ali Altalbe, "Hybrid optical-radio transmission system link quality: link budget analysis,"
[40] IEEE Access, vol. 8, pp. 65983-65992, 2020.
[41] Khan MN, Naseer F., "IoT based university garbage monitoring system for healthy environment for students," In2020 IEEE 14th International
[42] Conference on Semantic Computing (ICSC) 2020 Feb 3, pp. 354-358.
[43] Khan MN, Hasnain SK, Jamil M., "Digital Signal Processing: A Breadth-first Approach," Stylus Publishing, LLC; 2016 May 15.
[44] Tariq F, Rashid M, Khan MN., "Implementation of smart homes and industrial automation system with secure communication over GSM,"
[45] Universal Journal of Electrical and Electronic Engineering, vol. 3, no. 4, pp. 10, 2015.
[46] Khan MN, Rizvi UH., "Antenna beam-forming for a 60 Ghz transceiver system," Arabian Journal for Science and Engineering, vol. 38, no. 9, pp. 2451-64, 2013.
[47] Jamil, Mohsin, Muhammad Nasir Khan, Saqib Jamshed Rind, Qasim Awais, and Muhammad Uzair, "Neural network predictive control of vibrations in
[48] tall structure: An experimental controlled vision," Computers & Electrical Engineering, vol. 89, pp. 106940, 2021.
[49] Khan MN, Jamil M, Gilani SO, Ahmad I, Uzair M, Omer H., "Photo detector-based indoor positioning systems variants: A new look,"
[50] Computers & Electrical Engineering, vol. 83, pp. 106607, 2020 May 1.
[51] Kashif H, Khan MN, Altalbe A., "Hybrid optical-radio transmission system link quality: link budget analysis," IEEE Access, vol. 8, pp. 65983-92, 2020 Mar 18.
[52] J. Lee et al., "Development of a smart monitoring system for water quality based on IoT and cloud computing," Sustainability, vol. 9, no. 12, p. 2262, 2017.
[53] Y. Chen, C. Huang, and C. Xu, "A decision tree based cloud computing framework for water quality monitoring system," Journal of Hydrology, vol. 568, pp. 884-894, 2019.
[54] G. Bell, G. Wills, and J. Gray, "Designing Mobile Interfaces: Patterns for Interaction Design," O'Reilly Media, 2014.
[55] "FirebaseAuthentication,"Firebase.https://firebase.google.com/products/auth.