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Original Article

IoT-Based Real-Time Water Quality Monitoring for Sustainable Water Management: A Case Study in Somalia

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Abstract - *Water is an essential resource for life, but its quality is increasingly compromised by population growth, industrialization, and pollution. This paper explores the innovative application of the Internet of Things (IoT) in water quality monitoring, examining its potential to enhance the sustainability of our water resources and foster effective decision-making processes for water management and conservation. We propose and build a water quality monitoring system using IoT. The system collects the water's essential parameters, communicates with a central database for further analysis, displays it on a web application, and sends an SMS Message to the management of the wells. The system is designed to be low-cost and easy to deploy. It is suitable for use in developing countries like Somalia, where access to clean water is a significant challenge. The system has been tested in Somalia and has shown promising results.*

Keywords - *Water quality, IoT, pH sensor, Turbidity sensor, Conductivity sensor.*

1. Introduction

Water is an invaluable resource essential for the survival and well-being of all living organisms [1, 2]. However, the increasing population growth, industrialization, and pollution have significantly compromised the quality of water sources worldwide [3-5]. There is a growing need for efficient and real-time monitoring systems to address this pressing challenge that can provide accurate data on water quality parameters [6-11].

In recent years, the Internet of Things (IoT) technology has revolutionized how we interact with the physical world, offering unprecedented opportunities for monitoring and managing various environmental factors. In this context, a water quality monitoring system based on IoT has emerged as a promising solution, enabling continuous and remote monitoring of water bodies [12-14].

Access to clean drinking water is a significant challenge in Somalia, with only 30% of Somalis having access to clean water. Most of the population is vulnerable to several life-threatening diseases [15]. Lack of access to clean water also affects children's development and education, as girls are often forced to spend half the day fetching water and miss school [16]. In addition, accessing groundwater is difficult and expensive in much of the country due to low rainfall and widely deep groundwater tables. Most groundwater sources in the country have salinity levels above the required standard for drinking water [17]. Lack of clean drinking water can severely affect human health and the environment. Drinking contaminated water can lead to various health problems, including diarrhoea, cholera, typhoid, and other waterborne illnesses. These illnesses can be hazardous for vulnerable populations, such as children, pregnant women, and people with weakened immune systems [18].

Extracting and consuming water at unsustainable rates can lead to water scarcity, water stress, and freshwater resource depletion. This can have various environmental consequences, including damage to aquatic ecosystems and reduced biodiversity [19]. The lack of clean drinking water can also have economic consequences, such as lost productivity and income due to illness and the cost of treating waterborne illnesses [20].

Additionally, lack of access to clean water can have social consequences, limiting education and opportunities for women and girls and potentially leading to resource conflicts. It has far-reaching consequences on human health, the environment, and society. It is crucial to prioritize sustainable water management practices and ensure universal access to clean and safe drinking water [21]. Somalia faces significant challenges in water quality monitoring due to a need for adequate infrastructure.

A comprehensive monitoring system needs to be improved to assess and address the quality of water sources, leading to potential health and environmental risks [22].

Somalia can improve its environmental management by establishing a robust water quality monitoring system. Such a system would enable the timely detection of pollutants and contaminants, allowing authorities to implement targeted interventions to safeguard human health and aquatic ecosystems [23]. Regular monitoring would also facilitate informed decision-making regarding water resource allocation, pollution prevention, and sustainable development practices, ultimately preserving the fragile environment for future generations [24].

This research paper explores the innovative application of IoT in water quality monitoring, examining its potential to enhance the sustainability of our water resources and foster effective decision-making processes for water management and conservation. We propose and build a water quality monitoring system using the Internet of Things (IoT). The system collects the water's essential parameters, communicates with a central database for further analysis, displays it on a web application, and sends an SMS Message to the management of the wells.

2. Related Work

Water quality monitoring systems utilize advanced sensor technologies and real-time data analysis to assess aquatic ecosystem's condition and ensure clean drinking water availability. These systems provide accurate information about pH, temperature, dissolved oxygen, and pollutants [25]. Ongoing advancements are necessary to address evolving environmental challenges and protect our valuable water resources. Below is discussed the related work done by researchers worldwide who have done multiple studies on water quality monitoring systems.

Arias-Rodriguez et al. proposed using an extreme learning machine to integrate remote sensing and the Mexican water quality monitoring system. Their system combines data from Landsat-8 OLI, Sentinel-3 OLCI, and Sentinel-2 MSI with field measurements from the Mexican national water quality monitoring system to train an extreme learning machine, a support vector regression, and a linear regression for estimating Chlorophyll-a, Turbidity, Total Suspended Matter, and Secchi Disk Depth. Remote sensing supports monitoring system tasks, and as it is gradually integrated, water quality monitoring programs will become of higher quality [26]. Clyne and Deen proposed a low-cost multi-parameter water quality monitoring system. The system comprises low-cost, simple-to-use electrochemical sensors with high sensitivity, specially built sensor readout circuitry, and a smartphone app with wireless connectivity. The device can detect BPA with a limit of detection of 10 nM while simultaneously monitoring pH, free chlorine, and temperature with sensitivities of 57.5 mV/pH, 186 nA/ppm, and 16.9 mV/°C, respectively. The system offers a universal platform technology that makes it simple to incorporate and configure additional water monitoring sensors [27].

Jerom and Manimegalai proposed an IoT-based intelligent water quality monitoring system using the cloud. The system proposes monitoring water quality in water bodies using IoT and deep learning. The system uses low-cost sensors to monitor water quality in real time and transmit the data to the cloud for analysis. The system can combat water pollution by continuously monitoring water quality and ensuring a safe water supply from any water bodies and resources [28].

Maiolo and Pantusa propose a study that analyzes the quality monitoring data of drinking water supply systems using multivariate techniques. The analysis considered several chemical–physical parameters collected from 2013-2020 for some drinking water supply systems in the Emilia-Romagna region, Italy. Principal Component Analysis (PCA) and Cluster Analysis (CA) methods were used to process and reduce the data's dimensionality, highlight the parameters that have the most significant influence on the qualitative state of the supplied water, and identify clusters [29].

3. Methods

In this study, we propose and build an Internet of Things (IoT) based real-time monitoring system for assessing water quality in wells in Somalia. The system is designed to continuously monitor essential parameters and contaminants that can affect the safety and suitability of water for consumption. It consists of various sensors, including an Arduino Uno microcontroller [30], pH sensor, turbidity sensor, temperature sensor, conductivity sensor, and a GSM/GPRS module for data transmission.

The sensors are deployed in wells across Somalia, providing real-time data on water quality. The sensors are calibrated using calibration standards and reference samples per established procedures to ensure accurate measurements. The collected data is transmitted in real-time to a web application through the GSM/GPRS module, enabling immediate data visualization and analysis. The web application presents the data in an easily interpretable format, allowing for continuous monitoring of the water quality in the wells. The system also incorporates real-time alerts for abnormal water quality conditions. The system's deployment in the field considers practical aspects such as system robustness and reliability in suitable environments. The duration of field deployment and any encountered challenges are documented, further contributing to understanding real-time monitoring of water quality in wells in Somalia. Figure 1 shows the proposed system architecture.

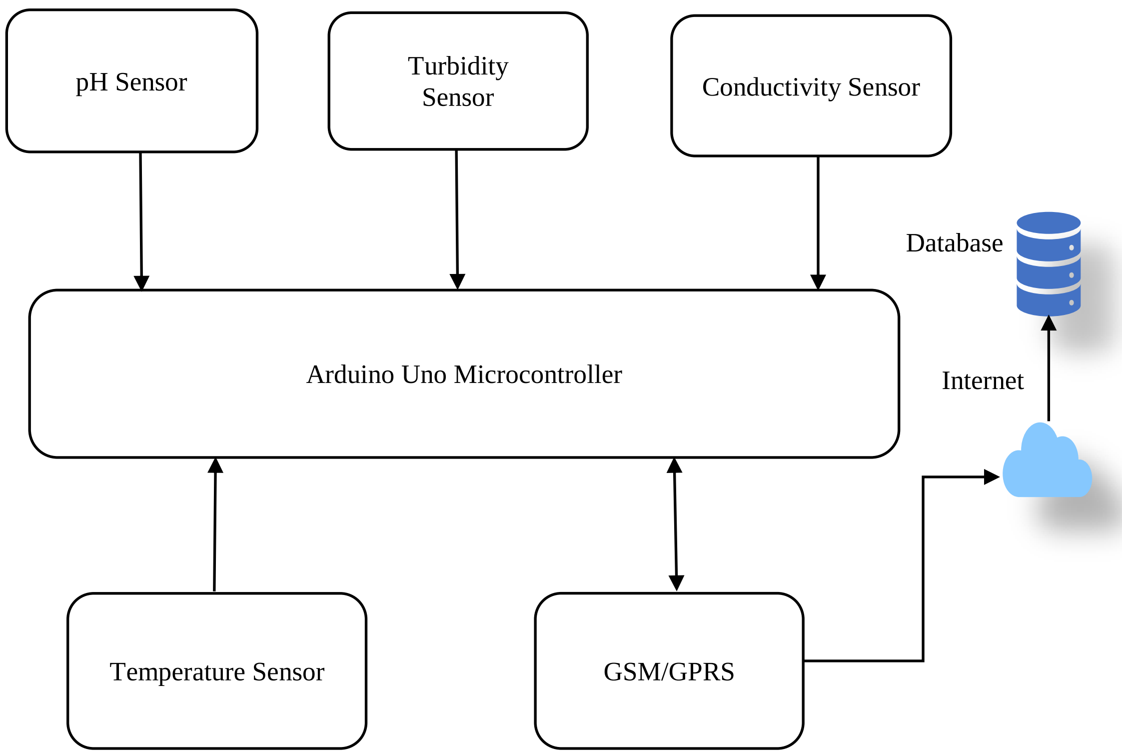

Fig. 1 Proposed system architecture

3.1. Arduino Uno

The Arduino Uno [30] is based on the ATmega328P microcontroller and features a set of digital and analog input/output pins. It offers 14 digital input/output pins, among which six can be used as Pulse Width Modulation (PWM) outputs and six analog input pins. These pins enable the connection of various sensors, actuators, and other electronic components to interact with the board [31]. This board is selected as the main board for the sensors to process sensor data and send the processed data to a central database.

3.2. pH Sensor

A pH sensor is a device used to measure the acidity or alkalinity of a solution. It is commonly used in scientific research, environmental monitoring, and industrial applications. The sensor detects the hydrogen ions (H+) concentration in a solution and provides a corresponding pH value. pH sensors typically comprise glass and reference electrodes, generating an electrical signal proportional to the pH level. These sensors play a crucial role in water quality analysis, agriculture, chemical processes, and other fields where pH measurement is essential for maintaining optimal conditions or ensuring safety [32].

3.3. Turbidity Sensor

A turbidity sensor is a device used to measure the level of cloudiness or turbidity in a liquid. It is commonly employed in environmental monitoring, water treatment processes, and scientific research. The sensor works by emitting light into the liquid and measuring the amount of light scattered or absorbed by suspended particles or impurities. The turbidity level is usually expressed in Nephelometric Turbidity Units (NTU) or Formazin Turbidity Units (FTU). Turbidity sensors are crucial in assessing water quality, ensuring the efficiency of filtration systems, and monitoring changes in aquatic ecosystems [33].

3.4. Temperature Sensor (DS18B20)

The DS18B20 is a waterproof digital temperature sensor known for its accuracy and ease of integration. The 1-Wire protocol offers a wide temperature range (-55°C to +125°C) and high-resolution measurements (up to 0.0625°C). This sensor is commonly used in weather monitoring, industrial control systems, and other projects requiring reliable and precise temperature sensing in wet or harsh environments. Its waterproof design ensures protection against moisture and water immersion, making it suitable for various challenging conditions [34].

3.5. Conductivity Sensor

A conductivity sensor measures the electrical conductivity of a solution, indicating its ability to conduct electric current. It is widely used in water quality analysis, industrial processes, hydroponics, and environmental monitoring.

The sensor consists of two or more electrodes immersed in the solution, and the conductivity measurement is typically expressed in units of Siemens per centimetre (S/cm) or micro Siemens per centimetre (µS/cm). Conductivity sensors play a vital role in assessing water purity, monitoring chemical concentrations, and ensuring the effectiveness of water treatment and nutrient management processes in hydroponic systems [35].

3.6. GSM/GPRS Module

The SIM7600 is a series of 4G/LTE modules for high-speed wireless communication. These modules, such as the SIM7600A, SIM7600E, and SIM7600CE, offer support for various frequency bands, including LTE Cat-1, Cat-M1 (eMTC), Cat-NB1 (NB-IoT), and backward compatibility with 2G/3G networks.

They provide fast and reliable data transfer capabilities, making them suitable for applications requiring high-speed internet connectivity. The SIM7600 modules typically feature UART or USB interfaces for seamless communication with microcontrollers or host devices. With their versatility and support for multiple frequency bands, the SIM7600 series modules are ideal for a wide range of IoT, M2M, and mobile data applications [36].

4. Results and Discussion

The Internet of Things (IoT) based real-time monitoring system developed in this study effectively assessed drinking water quality in wells across Somalia. The system, consisting of various sensors and a GSM/GPRS module, continuously monitored essential parameters and contaminants that impact water safety and suitability for consumption.Real-time data on water quality were collected from the wells by deploying sensors, including an Arduino Uno microcontroller [30], pH sensor, turbidity sensor, temperature sensor, and conductivity sensor. The calibration of these sensors using established procedures and standards ensured accurate measurements throughout the monitoring process.

The collected data was transmitted in real-time to a web application via the GSM/GPRS module, enabling immediate visualization and analysis. The web application presented the data in an easily interpretable format, allowing for continuous monitoring of water quality trends in the wells. This real-time monitoring capability is crucial in promptly identifying and addressing water quality issues ensuring safe drinking water for the population. Figure 2 shows the web Application interface of the system.

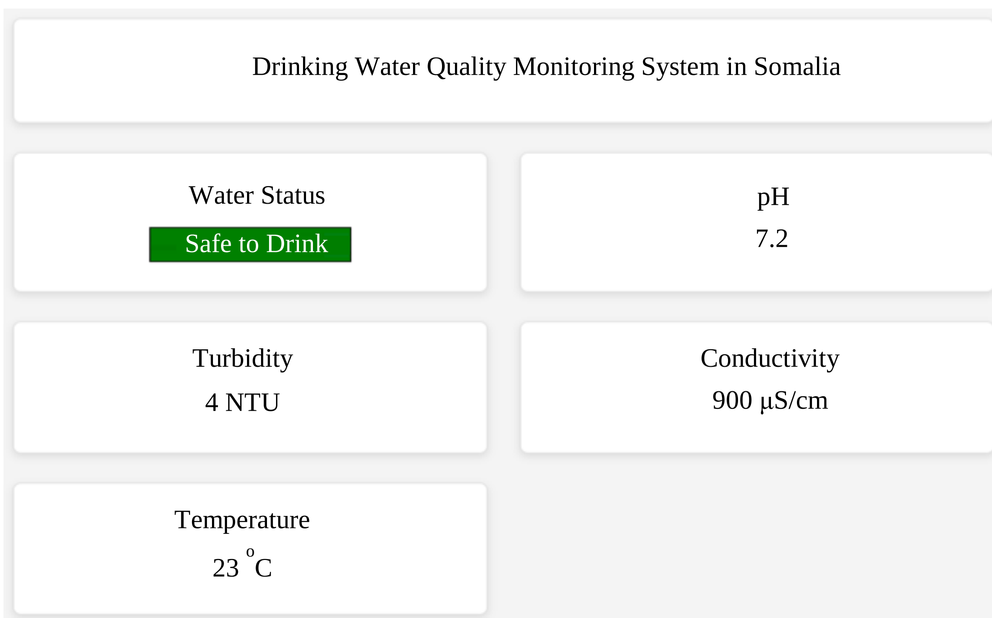

Fig. 2 Web application interface of the system

Furthermore, the system incorporated real-time alerts for abnormal water quality conditions. These alerts served as early warning indicators, notifying relevant stakeholders about potential risks and facilitating timely response and intervention.

The ability to receive real-time alerts enabled swift actions to safeguard the health and well-being of the communities relying on these wells. The field deployment of the system considered practical aspects such as system robustness and reliability in suitable environments.

The IoT-based real-time monitoring system presented in this study represents a significant advancement in monitoring drinking water quality in wells in Somalia. It offers a proactive approach to ensuring water safety by continuously monitoring critical parameters and providing immediate data visualization, analysis, and alerts.

By addressing the limitations of traditional water quality monitoring methods, this system can enhance public health outcomes and improve water management in Somalia. However, it is essential to note that the system's effectiveness and applicability may vary depending on specific local conditions, including variations in water sources, geological characteristics, and potential sources of contamination. Overall, the IoT-based real-time monitoring system demonstrates great potential in improving the management and quality of drinking water in wells in Somalia, and it serves as a valuable tool for decision-makers, water authorities, and communities to ensure the provision of safe and reliable drinking water sources.

5. Conclusion

In conclusion, this study's IoT-based real-time monitoring system has proven effective in assessing drinking water quality in Somali wells. By continuously monitoring essential parameters and contaminants, the system ensures the provision of safe and reliable drinking water sources.

The inclusion of real-time alerts enables prompt action to address water quality issues and safeguard public health. While local conditions may influence its applicability, the system significantly advances water safety management. It is a valuable tool for decision-makers, water authorities, and communities involved in ensuring clean drinking water.

References

[1] Santosh Kamble et al., "Hydrotrope Induced Synthesis of 1, 8-Dioxo-Octahydroxanthenes in Aqueous Medium," *Green Chemistry Letters and Reviews*, vol. 5, no. 1, pp. 101-107, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[2] Rayees Ahmad Wani, and Ishfaq Ahmad Bhat, "Water, Essential for Survival : Scrutinizing the Water Conflict of India-Pakistan," *The Journal of Oriental Research Madras*, pp. 151-159, 2022. [Google Scholar] [Publisher Link]

[3] Augustine Crispin C, and Sivakumar R, "Urbanization and Industrialization Impact on Surface Water in Coimbatore-Sulur Subwatershed," *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 8, no. 6, pp. 5097–5101, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[4] Shamima Shultana, and Ruhul A. Khan, "Water Quality Assessment, Reasons of River Water Pollution, Impact on Human Health and Remediation of Polluted River Water," *GSC Advanced Research and Reviews*, vol. 10, no. 2, pp. 107-115, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[5] Harrison Henry Boying, and Fang Ping, "Non-Point Source Pollution and Its Impact on Drinking Water Quality in River Nile- A Case Study of Juba South Sudan," *International Journal of Scientific and Research Publications (IJSRP)*, vol. 10, no. 9, pp. 483-496, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[6] Farmanullah Jan, Nasro Min-Allah, and Dilek Düştegör, "IoT Based Smart Water Quality Monitoring: Recent Techniques, Trends and Challenges for Domestic Applications," *Water*, vol. 13, no. 13, pp. 1-37, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[7] M. Manoj et al., "State of the Art Techniques for Water Quality Monitoring Systems for Fish Ponds using IoT and Underwater Sensors: A Review," *Sensors*, vol. 22, no. 6, pp. 1-17, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[8] Niranjan Reddy, M. Tholkapiyan, and S. Vijayan, "Comparative Analysis of Water Quality Parameters of Poondi Reservoir with Drinking Water Quality Standards for Sustainable Development," *SSRG International Journal of Civil Engineering*, vol. 10, no. 5, pp. 21-29, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[9] Navamuniyammal M et al., "Surface Water Quality Analysis in Thamirabarani River using Remote Sensing and GIS," *SSRG International Journal of Geoinformatics and Geological Science*, vol. 8, no. 1, pp. 1-8, 2021. [CrossRef] [Publisher Link]

[10] Arbind kumar, "Assessment and Monitoring of Water Quality of Manushmara River Basin in Sitamarhi District, North Bihar, India," *SSRG International Journal of Applied Chemistry*, vol. 4, no. 3, pp. 26-33, 2017. [CrossRef] [Publisher Link]

[11] Suraj Ghosh, Shibani Chaudhury, and Kumar Manoj, "An Appraisal of the Mayurakshi River System Water Quality – The Agrarian Basin," *SSRG International Journal of Agriculture & Environmental Science*, vol. 4, no. 4, pp. 50-56, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[12] Silvia Liberata Ullo, and G. R. Sinha, "Advances in Smart Environment Monitoring Systems using IoT and Sensors," *Sensors*, vol. 20, no. 11, pp. 1-18, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[13] Yuliarman Saragih et al., "Design of Automatic Water Flood Control and Monitoring Systems in Reservoirs Based on Internet of Things (IoT)," *2020 3rd International Conference on Mechanical, Electronics, Computer, and Industrial Technology (MECnIT)*, Medan, Indonesia, pp. 30-35, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[14] Wongpanya S. Nuankaew et al., "Internet of Things for Monitoring Fish Cage Water Quality," *International Journal of Engineering Trends and Technology*, vol. 71, no. 6, pp. 212-220, 2023. [CrossRef] [Publisher Link]

[15] Oxfam, Contaminated Water a Grave Threat to SOMALIS, Oxfam International, 2014. [Online]. Available: https://www.oxfam.org/en/press-releases/contaminated-water-grave-threat-somalis

[16] UNICEF, Water, Sanitation and Hygiene, UNICEF Somalia, 2019. [Online]. Available: https://www.unicef.org/somalia/water-sanitation-and-hygiene#_ftn2

[17] FAO SWALIM, Charcoal Production in South Central Somalia, Food and Agriculture Organization of the United Nations, Somalia Water and Land Information Management, 2018. [Online]. Available: http://www.faoswalim.org/article/charcoal-production-south-central-somalia

[18] Rajindar K. Koshal, "Water Pollution and Human Health," *Water, Air, and Soil Pollution*, vol. 5, pp. 289-297, 1976. [CrossRef] [Google Scholar] [Publisher Link]

[19] Rajat K. Chakraborti, Jagjit Kaur, and Harpreet Kaur, "Water Shortage Challenges and a Way Forward in India," *American Water Works Association*, vol. 111, no. 5, pp. 42-49, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[20] Anja du Plessis, "Current and Future Water Scarcity and Stress: Current Water Availability, Quality and Risks with a Specific Focus on South Africa," vol. 2, pp. 13-25, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[21] Matthew Goff, and Ben Crow, "What is Water Equity? The Unfortunate Consequences of a Global Focus on 'Drinking Water'," *Water International*, vol. 39, no. 2, pp. 159-171, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[22] Abdukadir Dahir Jimale et al., "Mitigating the Impact of Floods : An IoT-Driven Monitoring and Alert System for Somalia's Rivers," *SSRG International Journal of Electrical and Electronics Engineering*, vol. 10, no. 6, pp. 120-125, 2023. [CrossRef] [Publisher Link]

[23] Yohanis Birhanu, and Genemo Berisa, "Assessment of Solid Waste Management Practices and the Role of Public Participation in Jigjiga Town, Somali Regional State, Ethiopia," *International Journal of Environmental Protection and Policy*, vol. 3, no. 5, pp. 153-168, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[24] Wouter Buytaert et al., "Citizen Science in Hydrology and Water Resources: Opportunities for Knowledge Generation, Ecosystem Service Management, and Sustainable Development," *Frontiers in Earth Science*, vol. 2, pp. 1-21, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[25] Howard B. Glasgow et al., "Real-Time Remote Monitoring of Water Quality: A Review of Current Applications, and Advancements in Sensor, Telemetry, and Computing Technologies," *Journal of Experimental Marine Biology and Ecology*, vol. 300, no. 1-2, pp. 409-448, 2004. [CrossRef] [Google Scholar] [Publisher Link]

[26] Leonardo F. Arias-Rodriguez et al., "Integration of Remote Sensing and Mexican Water Quality Monitoring System using an Extreme Learning Machine," *Sensors*, vol. 21, no. 12, pp. 1-27, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[27] Arif Ul Alam, Dennis Clyne, and M. Jamal Deen, "A Low-Cost Multi-Parameter Water Quality Monitoring System," *Sensors*, vol. 21, no. 11, pp. 1-15, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[28] Jerom B. Ajith, R. Manimegalai, and V. Ilayaraja, "An IoT Based Smart Water Quality Monitoring System using Cloud," *2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE)*, Vellore, India, pp. 1-7, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[29] Mario Maiolo, and Daniela Pantusa, "Multivariate Analysis of Water Quality Data for Drinking Water Supply Systems," *Water*, vol. 13, no. 13, pp. 1-14, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[30] Okpare Onoharigho Anthony et al., "Development of a Wireless System to Check the Water Level in a Storage Tank," *International Journal of Recent Engineering Science*, vol. 10, no. 2, pp. 40-45, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[31] Abdukadir Dahir, Mohamed Omar, and Yahye Abukar, "Internet of Things Based Agricultural Drought Detection System: Case Study Southern Somalia," *Bulletin of Electrical Engineering and Informatics*, vol. 12, no. 1, pp. 69-74, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[32] Wen-Ding Huang et al., "A Flexible pH Sensor Based on the Iridium Oxide Sensing Film," *Sensors and Actuators A: Physical*, vol. 169, no. 1, pp. 1-11, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[33] Ahmad Aftas Azman et al., "A Low Cost Nephelometric Turbidity Sensor for Continual Domestic Water Quality Monitoring System," *2016 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS)*, Selangor, Malaysia, pp. 202-207, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[34] R. A. Koestoer et al., "A Simple Method for Calibration of Temperature Sensor DS18B20 Waterproof in Oil Bath Based on Arduino Data Acquisition System," *AIP Conference Proceedings*, vol. 2062, p. 020006, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[35] Abdulshakur Abdullahi Diiso et al., "Monitoring and Evaluation of Air Quality : A Case Study of Mogadishu, Somalia," vol. 7, no. 9, pp. 31-36, 2022. [Google Scholar] [Publisher Link]

[36] Davide Aguiari et al., "Monitoring Electric Vehicles on the Go Davide," *2022 IEEE 19th Annual Consumer Communications & Networking Conference (CCNC)*, Las Vegas, NV, USA, pp. 885-888, 2022. [CrossRef] [Google Scholar] [Publisher Link]