International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 09 September 2024
Page No: 2331 - 2341
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0320

Review on Evaluation and Analysis of Water Quality Monitoring Systems Using IoT

Santhosini R[1], *Subhiksha U K*[2], *Dr.V E Jayanthi*[3]
[1,2]*PG – Biomedical Engineering, PSNA College of Engineering and Technology, Dindigul, Tamil Nadu, India.*
[3]*Professor – Biomedical Engineering, PSNA College of Engineering and Technology, Dindigul, Tamil Nadu, India.*
Emails: *santhoshinir23mebme@psnacet.edu.in*[1], *subhikshauk23mebme@psnacet.edu.in*[2], *hodbio@psnacet.edu.in*[3]

Abstract

Water is an important resource and it's more essential for maintain temperature in living organisms, economic growth and sustainable development as the water is prone to pollution it is important for real-time monitoring. The pivotal role of Internet of Things (IoT) technology in developing water quality management practices for the advancement of sustainable development. By leveraging insights gleaned from IoT-driven data collection and analysis, stakeholders can optimize resource allocation, enhance operational efficiency, and minimize environmental impact. The adoption of IoT technology in water quality management not only ensures the integrity of water resources but also heralds a future where sustainability and innovation intersect to address the challenges of water resource stewardship. Through harnessing IoT sensors and devices, we empower ourselves with the capability to continuously monitor various parameters of water quality, such as pH levels, dissolved oxygen content, turbidity, and pollutant concentrations. Moreover, the utilization of IoT facilitates not only data collection but also data analysis and interpretation in near real-time. This proactive approach enables decision-makers to implement targeted interventions swiftly, safeguarding water resources and public health. This real-time data collection not only provides us with accurate insights into the current state of water quality but also enables proactive interventions to mitigate potential risks associated with pollution or contamination. This review paper discusses the importance of accurate data collection and significance of real-time monitoring for effective water quality management and provide understanding into the evaluation of water quality management system emphasing the need for analyzing the continuous improvement and innovation in management system.

Keywords: *Water quality management system, Water quality measurement, Analysis of Variance (ANOVA), Internet of Things (IOT).*

1. Introduction

Water is an irreplaceable resource that strengthens the functioning of our planet's ecosystems. Earth is filled with 71% of unusable salt water and less than 1% of water is available in freshwater form. The freshwater sources are rivers, lakes, ponds and underground aquifers. The World Water Development report from the UN (United Nations) has sounded a critical alarm: an estimated 50% of the global population will soon confront severe water scarcity [1]. Regions like Africa and Asia, encompassing countries such as Cambodia, Bangladesh, China, and India still in the developmental phase are expected to bear the brunt of this crisis. Projections indicate in the year 2050, a staggering 70% of India's population will reside in urban areas. However, the challenge looms larger as water reservoirs diminish due to multiple factors like reduced rainfall and unsustainable usage. This statement presents a formidable obstacle in ensuring adequate resources water and electricity to sustain such budding populations. Nonetheless, there exists a light of hope in leveraging sensor technology and Information and Communication Technology (ICT) to effectively manage and conserve water resources for future generations. The following sessions explains the water resources quality maintaining in India. India is a country depends on the water sources for its daily activities. In recent years, Indian rivers have been subjected to overload. The primary cause stems from the mineral-laden basins, leading to their excessive exploitation and consequent pollution of river water. The toxic wastes, including sewage, industrial, and agricultural runoff, contaminates the river, making the water unfit for everyday consumption. In this case water purification is needed to reuse for overcome the scarcity of water. (Refer Figure 1)

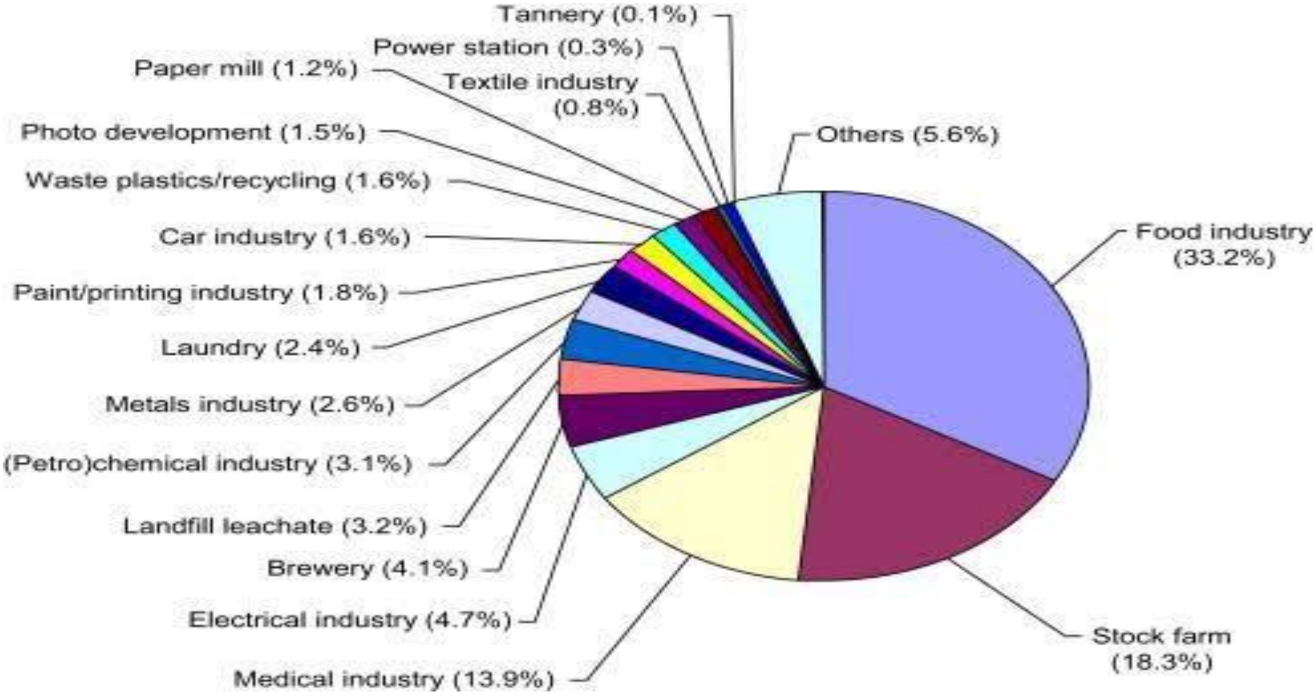

Figure 1 **Case and Mortality Chart for Ten Most Common Types of Waste Water in India (26)**

Water Quality Monitoring (WQM) system is also required for checking the quality of water. WQM system gathers real-time data from the specified locate on for assessing the quality of water and then the information’s are transmitted to the data center to check the condition of the water. When data falls within the expected parameters, no immediate action is required. However, any deviations beyond the norm trigger notifications to the communities surrounding the river basins, accompanied by specific precautions to mitigate potential water-related issues, effectively preventing any waterborne epidemics. In India, water quality monitoring is done according to a traditional technique which involves collection of samples from the site and analyzing the samples in a laboratory. This technique is time consuming and takes a day or two to get the results, so the available data are not real time. Consumption of such water can lead to waterborne diseases in people around the basins. The rise of Internet of things (IoT) offers a promising solution to address the aforementioned challenge, particularly by facilitating real-time data collection, especially within river basin areas and it is accomplished with the help of the IoT system called the WQM system. To measure the quality of water, different types of sensors are used such as Figure 2 Give the framework of WQM system using IOT. WQM generally consists of different water quality sensors, such as T, pH, dissolved oxygen (DO), electrical conductivity (EC), biochemical oxygen demand (BOD), NO 3, and total dissolved solids.

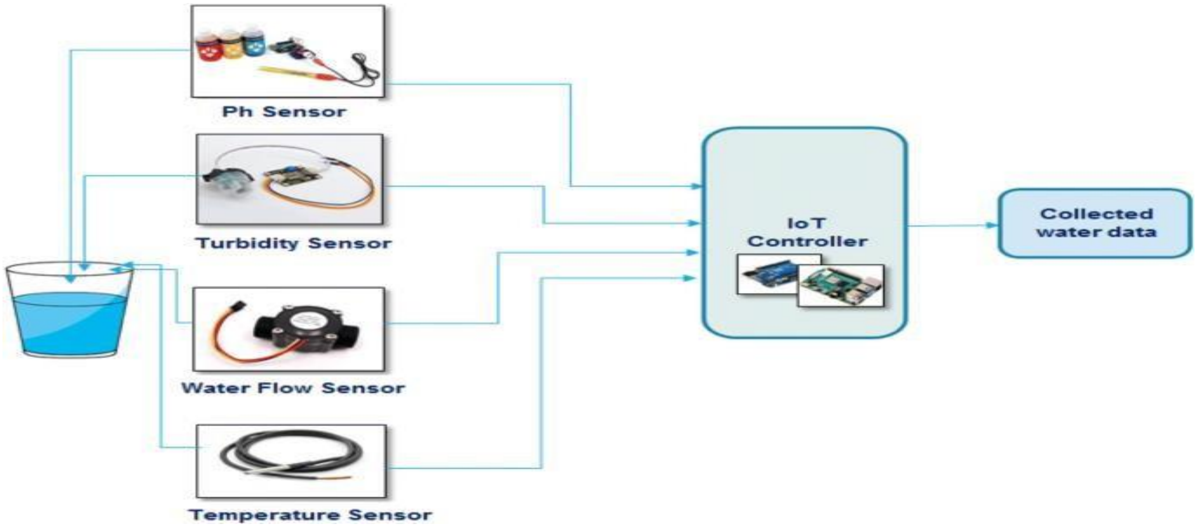

Figure 2 Framework of IoT in WQM System [26]

By conducting a thorough evaluation, stakeholders, regulatory bodies, researchers, and policymakers can measure the system's capabilities in accurately detecting and quantifying various contaminants, pollutants, microbial agents, and physical parameters within water bodies. Moreover, it aids in identifying potential weaknesses, improving detection limits, enhancing response times, and ensuring agreement with established water quality standards and regulations. This IOT-based water quality monitoring system helps as to reduce nonrenewable water losses and reduce water consumption in the field of agriculture.

2. Water Quality Monitoring System

A thorough monitoring programme conducted between 2006 and 2013 produced important understanding on the Ghataprabha River, a tributary of the Krishna River [1].The map of the Ghataprabha basin, where the River Krishna merges at Chikkasangama, is represented in Figure 2. Current systems focus less on the understanding that can be derived from data and more time on data collection. Tank water levels must be manually measured. Readings from pressure and flow meters are manually taken in a delivery system. To assess the quality of the water, samples are taken, and the results are examined in labs; this process takes a few days. This may be changed with smart water analytics by presenting real-time data in front, allowing analysts to focus on analysis and action in a timely and cost-effective manner. (Refer Figure 3)

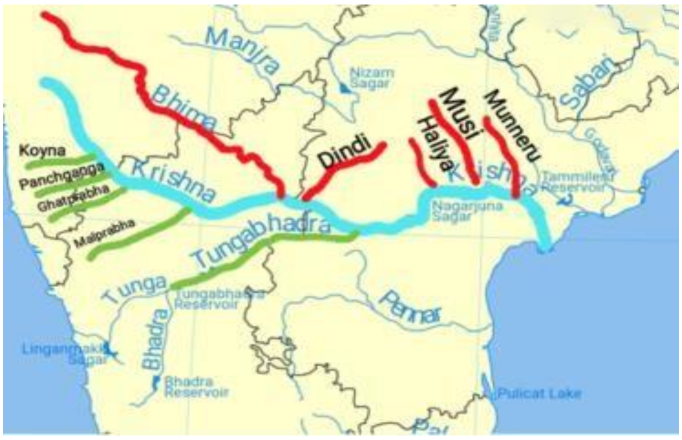

Figure 3 River Ghataprabha Basin Merges in River Krishna at Chikkasangama. (Source: Google)

Ecological monitoring of the water environment is done through the use of a smart sensor interface device known as Smart WQM for a water quality monitoring system. The main objective is to provide quick and cost-effective real-time data on water quality [3]. The Intelligent WQM IoT system was created for industrial use and provides low-cost, dependable real-time WQM data, which is used to confirm water quality and is essential to Smart city programme is discussed [4]. It claims that there is not enough support for watershed management (WQM) and highlights the need for this system that can make decisions in order to help watershed managers are explained [5] & [24]. The WQM system was created especially for drinking water with the goal of measuring and evaluating water quality in order to quickly resolve any possible problems. Water quality is predicted using an anomaly detection algorithm, which agreements low energy usage and a long system life [6]. In order to collect data continuously and incorporate many water quality metrics at a higher sampling rate, an IoT water monitoring system was created [7]. This study examines several IoT designs for WQM and identifying knowledge gaps in IoT-based WQM systems already in use, such as the lack of a standardized method for measuring, reporting, or exchanging analyzed WQM data [8] & [9]. An inexpensive Raspberry Pi for WQM has been used to power an IoT system that allows for real-time control over water flow and notifies authorities when deviations in WQM parameter readings occur [10]. This device keeps an eye on physicochemical parameters and makes real-time data available for analysis and measurement via the cloud. In order to provide more accurate results, the suggested approach fills a research need by incorporating biological characteristics [11]. The WQM framework is designed to monitor physical- chemical parameters remotely in rivers and wells using a mobile application. It integrates IoT, Cloud, and Big Data and aims to rapidly notify the government in the event of WQ irregularities [12],[14] & [19]. WQM uses physicochemical factors to develop a real-time IoT prototype that maintains and restores contaminated water sources. More sensors and edge computing are two suggestions for improvement for efficient real-time monitoring [15]. Water pollution's effects on the environment are evaluated using a different WQM system that is customized for the region's flora and fauna [16] & [23]. This system was developed to assist farmers and allows for the real-time evaluation of water quality based on physical-chemical criteria. It ensures that aquatic life is healthy by urging quick action in the event of abnormalities [17] & [24]. Kafli and Isa [18] stress the significance of an accurate environmental audit to alert officials about defects in water quality. In addition, a real-time IoT-based river and lake monitoring system is given for flood analysis and WQ. They talk about an IoT-based scalable WQM system for aquaculture that is inexpensive and low-power. (Refer Figure 4)

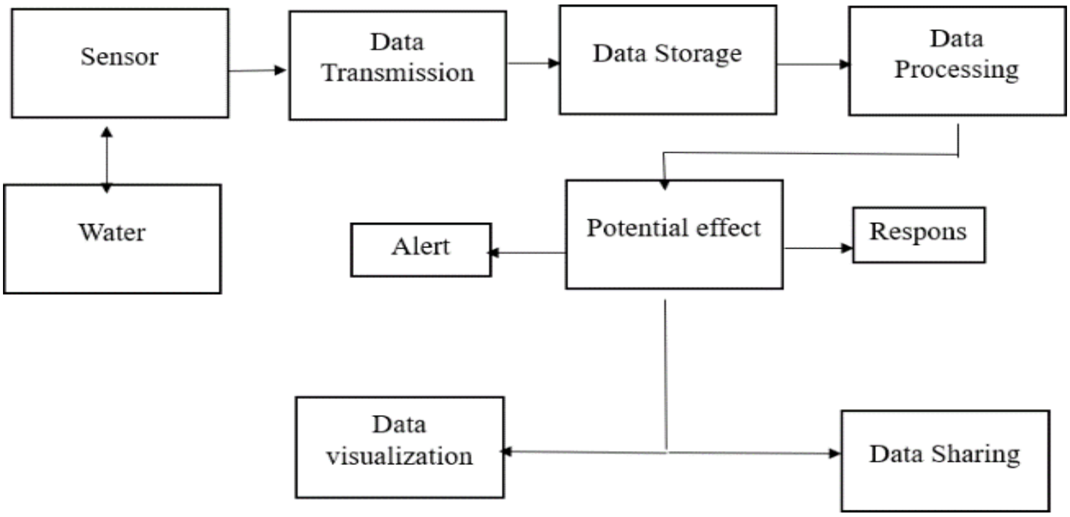

Figure 4 **Smart Water Quality Monitoring System**

The methodology used is linear regression, which is used to determine the connection between two or more factors, namely the independent and dependent variables, with respect to the Ghataprabha River before it merges with the Krishna River at Chikkasangama. Our goal in doing this analysis is to better understand how variations in the independent variable affect the dependent parameter. By attempting to minimize the sum of squares, this regression helps to understand the distribution of the data. The samples are then subjected to one-way ANOVA,which enables us to identify variations in water quality. We choose the Ghataprabha River for our research because, as [2] & [22] indicate, no previous thorough studies have been conducted on this specific Krishna tributary.

2.1.Method Used To Develop WQM System

The Ghataprabha river, a tributary flowing along the right bank of the Krishna river, primarily courses through Karnataka, although its origin remains unknown but is located in Maharashtra. The river enters Karnataka at Maranhol, situated at coordinates 16.054253°N, 74.368739°E. Extending a length of 283 km, it eventually merges with the Krishna river at Chikkasangama (coordinates 16.1957°N, 75.4417°E).

2.1.2. Inclusion Criteria

2.1.1. Exclusion Criteria

1. Article published in scientific journals in English only
2. Article that focused on the development of different systems, application, technologies using IoT, Machine learning and Deep learning
3. Article focused on IoT and ML based algorithms

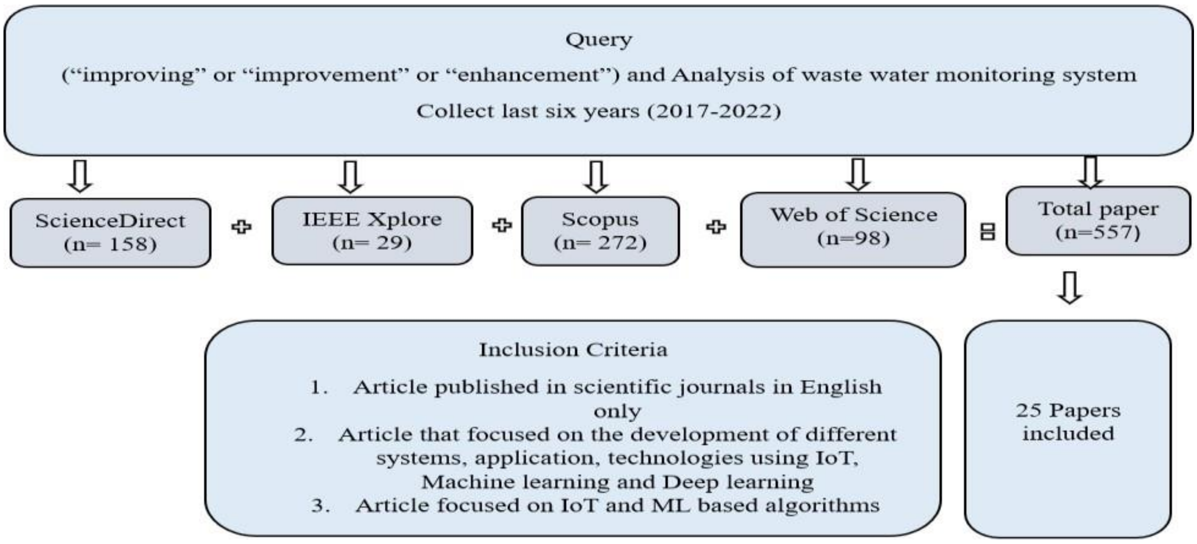

Figure 5 Inclusion Criteria

Sampling: Water samples are systematically gathered from government-approved stations across Karnataka, encompassing all seasonal variations—summer, rainy, and winter periods. Table 1 provides a comprehensive overview of the sampling stations specifically designated for the Ghataprabha River. (Refer Figure 5)

Table 1 Sampling station of the Ghataprabha River

Station Code	Locations	Coordinates
1163	Ghatprabha At W.A. Point to Gokak Town	16.1592°N, 74.8156° E
1185	Ghatprabha At Downstream Of Mudhol Rd.Cross Bdg	16.3333°N, 75.2858° E

IoT System Specification: The beginning of IoT has transformed analytical procedures by facilitating real-time data acquisition. This technology enables the deployment of devices even in the most remote and challenging terrains, inaccessible to human presence, thereby ensuring data accuracy and accessibility. The WQM system's architecture follows a three-tier structure: the physical layer integrates tangible sensors like pH, temperature (T), dissolved oxygen (DO), biochemical oxygen demand (BOD), electrical conductivity (EC), nitrate (NO3), total dissolved solids (TDS), among others [18]. The intermediary link layer primarily incorporates transceivers responsible for data transmission and reception, along with an analog-to-digital converter (ADC) essential for converting analog signals into coherent digital data. The topmost application layer encompasses the actual data analysis processes. chart.1 represent the layered Structure for WQM system. The analysis methodology encompasses various statistical techniques such as linear regression, one-way ANOVA, support vector machine (SVM), artificial neural network (ANN), which dedicates the layered structure of the WQM system [21]. (Refer Figure 6)

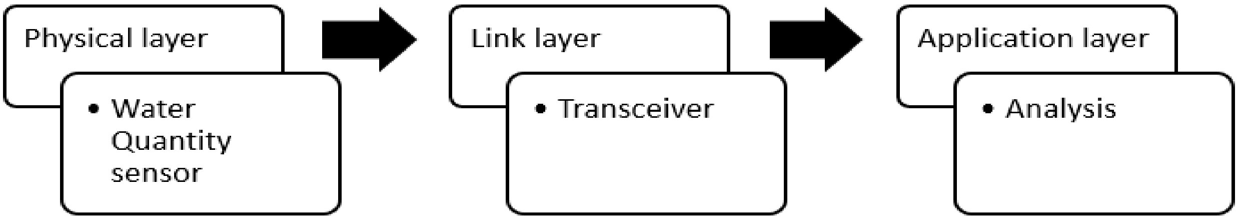

Figure 6 **Layered Structure for WQM**

Statistical Analysis Methods: Utilization of linear regression analysis help to establish the correlation between diverse physicochemical parameters within the water samples. Subsequently, employing one-way ANOVA enables a comprehensive assessment of the collected water sample's quality. A detailed discussion on linear regression and one-way ANOVA follows in the subsequent section.

Linear Regression: At its core, linear regression serves as a method to determine the association between two variables: the independent (x) and the dependent (y) variables. It essentially evaluates the strength and nature of the relationship between these variables. The linear regression equation, expressed as $y = ax + b$, encompasses 'b' as the intercept (representing the value of y when $x = 0$) and 'a' as the slope of the regression line. A positive 'a' indicates that y increases with x, indicating a positive relationship between x and y. Conversely, a negative 'a' signifies that y decreases with increasing x, indicating a negative relationship. An 'a' value of 0 implies no detectable relationship between x and y [25]. Figure 7 denotes the graph for the combination of T and DO based on the present value and predicted value. Additional crucial factors in linear regression include:

Multiple R: This correlation coefficient ranges between -1 and 1, make clear the strength of the linear relationship between two variables. A value of 1 signifies a strong positive relationship, -1 denotes a robust negative relationship, while 0 signifies a lack of any relationship between the variables.

$$\text{Multiple R} = \sqrt{R}$$

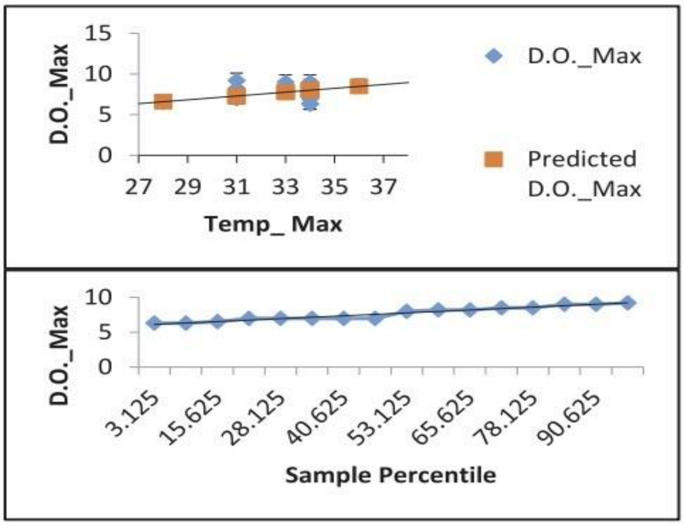

Figure 7 **Linear Regression Graph for the Combination of T and DO [25]**

R Square (R2): This metric represents the coefficient of determination, indicating the proportion of data points that align with the regression line. It implies that approximately 91% of the values conform to the regression model, clarifying the model's accuracy. Mathematically, it is calculated as:

$$\text{R Square(R2)} = 1 - \frac{\text{sum of square error}}{\text{Total sum of squre}}$$

Standard Error: This metric quantifies the average deviation of data points from the regression line. A smaller value indicates greater confidence in the accuracy of the regression equation, as it signifies reduced dispersion of data points around the line.

$$\text{Standard Error} = \sqrt{\frac{\text{sum of square error}}{(n-k)}}$$

Adjusted Square: This parameter, known as adjusted R2, pertains to the independent variables within the linear regression analysis. It accounts for the model's adequacy concerning the number of predictors. It is computed as:

$$\text{Adjusted square} = 1 - \frac{\text{Mean square error}}{\text{Mean of square total}}$$

Significance F: This metric indicates the reliability of the obtained results. A significance F value below 0.05 signifies a robust model, whereas a value exceeding 0.05 suggests considering alternative independent variables for the regression analysis.

One-Way ANOVA: Utilizing the F distribution method, one-way ANOVA compares multiple sample means. This statistical technique, named 'one-way' due to its dependency on a single independent variable, assesses whether samples are drawn from the same group of sample means. The null hypothesis investigates the statistical significance in the relationship between these sample means. The output of one-way ANOVA includes F statistics, illustrate the variance between sample means in contrast to the variance within the samples.

$$F = \frac{\text{Mean square factor}}{\text{Mean square error}}$$

Degree of Freedom Factor = n-1

Degree of Freedom Error = Total number of observations – number of factors

The p-value serves as a crucial factor in assessing the significance of the null hypothesis, aiding in the decision-making process regarding its acceptance or rejection. A p-value equal to or less than 0.05 supports the rejection of the null hypothesis; otherwise, accepting the null hypothesis becomes plausible. Similarly, the F-value, expressed in the above equation, plays a key role in determining the statistical significance of the test. The F-critical value acts as a threshold, beyond which the F-value is improbable to surpass. If the calculated F-value exceeds the F-critical value, the hypothesis is typically rejected, aligning with findings referenced in [2].

Rainy season: During the rainy season, heightened water levels in the Ghataprabha river at Station 1163 in Gokak Town were observed. A detailed analysis, as per Table 2, revealed that all water quality parameters, except for NO3, were within the normal range. The NO3 parameter exhibited abnormal behavior, indicated by a significantly high F value of 6.88 and a P-value of 0.01, surpassing the critical F value, and with the P-value less than the α value of 0.05 [5]. This anomaly was attributed to the presence of pesticides from the surrounding fields, impacting water quality. On the other hand, at Station 1185 in Mudhol rd. Cross b., Karnataka, during the same rainy season, all water quality parameters, including both the F value and the P-value, fell within the prescribed normal range. In summary, the general observation of the Ghataprabha river during the rainy season highlights abnormal NO3 levels at Station 1163 due to pesticide runoff from nearby fields, while the water quality at Station 1185 remained within the normal range.

Table 2 One Way ANOVA Observation for Rainy Season [25]

Station 1163	Rainy season				Station 1185	Rainy season	
Parameter	F- value	P-value	F critical value		F- value	P-value	F critical value
DO	2.4803	0.1269	3.7870		1.3547	0.3485	3.7870
pH	1.9201	0.2044	3.7870		0.7069	0.6707	3.7870
EC	1.0670	0.4718	3.7870		1.0187	0.4906	3.7870
B.O.D	1.0143	0.4927	3.7870		1.0774	0.4621	3.7870
NO3	6.8846	0.0105	3.7870		0.8018	0.6109	3.7870
TDS	1.0905	0.4560	3.7870		1.0293	0.4853	3.7870

Winter season: In the winter season, the Ghataprabha river experiences a moderate water level, neither too low nor too R Square (R2): This metric represents the coefficient of determination, indicating the proportion of data points that align with the regression line. A value of, say, 91% implies that approximately 91% of the values conform to the regression model, elucidating the model's accuracy. Mathematically, it is calculated as:

$$1-\frac{sum\ of\ square\ error}{Total\ sum\ of\ squre}$$

During this period, an analysis of water quality was conducted at Station 1163 in Gokak Town with the finding presented in Table 3. The observations from this analysis indicate that, during the winter season, all water quality parameters at Station 1163 are within the normal range. Specifically, the F values for each parameter are below the critical F value, indicating normalcy. Additionally, the P-values associated with all water quality parameters are also within the normal range, surpassing the α value of 0.05. In summary, the winter season at Station 1163 Ghataprabha in Gokak Town demonstrates that water quality parameters are within acceptable limits, both in terms of F values and P-values, reflecting a normal and satisfactory condition.

Table 3 **One Way ANOVA Observation for Winter Season [25]**

Station 1163	Winter season				Station 1185	Winter season	
Parameter	F- value	P-value	F critical value		F- value	P-value	F critical value
DO	1.6990	0.2505	3.7870		0.9423	0.5302	3.7870
pH	1.0415	0.4793	3.7870		1.2310	0.3955	3.7870
EC	1.0302	0.4848	3.7870		0.9989	0.5006	3.7870
B.O.D	1.2060	0.4056	3.7870		2.1287	0.1701	3.7870
NO3	1.7697	0.2345	3.7870		0.8314	0.5931	3.7870
TDS	1.0536	0.4734	3.7870		0.9476	0.5274	3.7870

Table 4 **One Way ANOVA Observation for Summer Season [25]**

Station 1163	Summer season				Station 1185	Summer season	
Parameter	F- value	P-value	F critical value		F- value	P-value	F critical value
DO	0.5884	0.7496	3.7870		1.7991	0.2282	3.7870
pH	1.1941	0.4105	3.7870		1.2182	0.4006	3.7870
EC	0.9975	0.5013	3.7870		1.0071	0.4964	3.7870
B.O.D	0.7347	0.6528	3.7870		2.6986	0.1068	3.7870
NO3	1.4768	0.3099	3.7870		3.6044	0.0562	3.7870
TDS	1.1872	0.4133	3.7870		0.8406	0.5876	3.7870

Summer Season: In the summer season, characterized by low water levels in the river, observations were made at Station 1163 Ghataprabha in Gokak Town as outlined in Table 4. The analysis indicates that during this season, all water quality parameters are within normal conditions. The criteria for determining normality are as follows, as summarized in Figure 8 for both Station 1163 and Station 1185 through One-Way ANOVA analysis: A parameter is considered within the normal range if its F-value is less than the F-critical value.

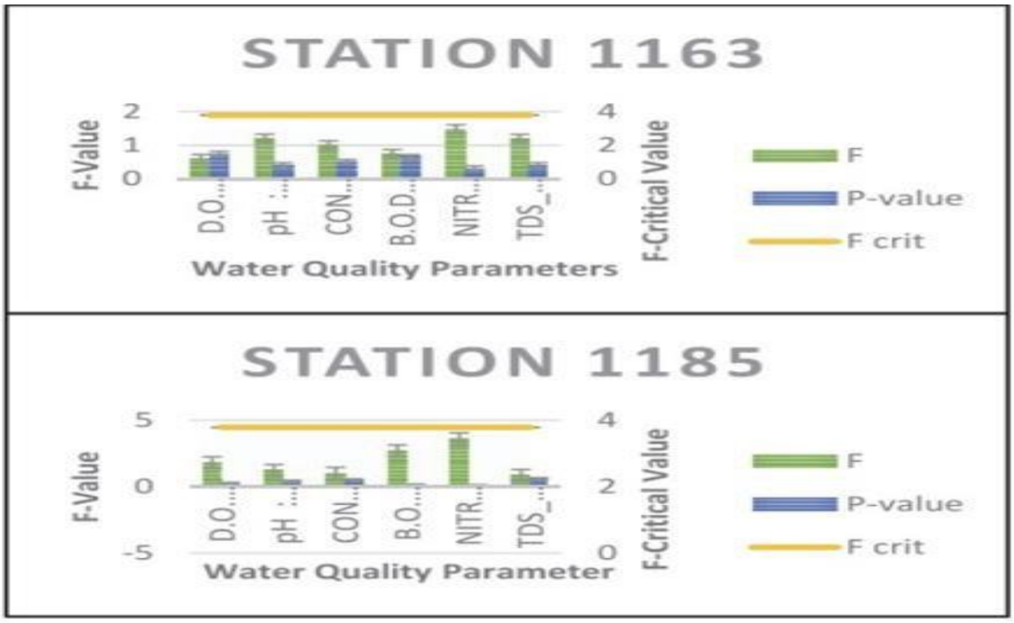

Figure 8 One-Way ANOVA Analysis of Summer Season [25]

Conclusion

Water pollution poses a significant threat to any nation, impacting public health, the economy, and biodiversity. Despite the existence of commendable smart water quality monitoring systems, the research landscape remains formidable. This review delves into recent studies by researchers aimed at enhancing water quality monitoring systems to be smart, energy-efficient, and highly effective. The objective is to enable continuous monitoring, with automatic alerts and notifications sent to relevant authorities for prompt action. The proposed model is both cost-effective and user-friendly, offering flexibility in its application. By testing three water samples, the system can classify the water as either potable or non-potable based on the results. Looking ahead, the recommendation is to incorporate cutting-edge sensors for detecting additional quality parameters, leverage wireless communication standards to enhance connectivity, and integrate IoT technology to create an advanced water quality monitoring system. This approach aims to ensure a swift response, ultimately safeguarding water resources and promoting immediate action for the well-being of communities.

References

[1]. Adu-Manu, K. S., Tapparello, C., Heinzelman, W., Katsriku, F. A., & Abdulai, J. D. (2017). Water quality monitoring using wireless sensor networks: Current trends and future research directions. ACM Transactions on Sensor Networks (TOSN), 13(1), 1-41.

[2]. Pujar, P. M., Kenchannavar, H. H., Kulkarni, R. M., & Kulkarni, U. P. (2020). Real-time water quality monitoring through Internet of Things and ANOVA-based analysis: a case study on river Krishna. Applied Water Science, 10(1), 1-16.

[3]. Myint, C. Z., Gopal, L., & Aung, Y. L. (2017, May). Reconfigurable smart water quality monitoring system in IoT environment. In 2017 IEEE/ACIS 16th international conference on computer and information science (ICIS) (pp. 435-440). IEEE.

[4]. Salunke, P., & Kate, J. (2017, February). Advanced smart sensor interface in internet of things for water quality monitoring. In 2017 International Conference on Data Management, Analytics and Innovation (ICDMAI) (pp. 298-302). IEEE.

[5]. Behmel, S., Damour, M., Ludwig, R., & Rodriguez, M. J. (2016). Water quality monitoring strategies—A review and future perspectives. Science of the Total Environment, 571, 1312-1329.

[6]. Jalal, D., & Ezzedine, T. (2017, October). Towards a water quality monitoring system based on wireless sensor networks. In 2017 International Conference on Internet of Things, Embedded Systems and Communications (IINTEC) (pp. 38-41). IEEE.

[7]. Salim, T. I., Alam, H. S., Pratama, R. P., Anto, I. A. F., & Munandar, A. (2017, October). Portable and online water quality monitoring system using wireless sensor network. In 2017 2nd International Conference on Automation, Cognitive Science, Optics, Micro Electro-Mechanical System, and Information Technology (ICACOMIT) (pp. 34-40). IEEE.

[8]. Lokuliyana, S., Jayakody, A., Bandara, N. B. R. P., Deshapriya, J. W. P., Kavinda, P. C., & Wijewickrema, T. L. (2018, August). A survey: IoT enable framework for water quality measurement and distribution. In 2018 13th International Conference on Computer Science & Education (ICCSE) (pp. 1-6). IEEE.

[9]. Kang, G., Gao, J. Z., & Xie, G. (2017, April). Data-driven water quality analysis and prediction: A survey. In 2017 IEEE third international conference on big data computing service and applications (BigDataService) (pp. 224-232). IEEE.

[10]. Moparthi, N. R., Mukesh, C., & Sagar, P. V. (2018, February). Water quality monitoring system using IoT. In 2018 Fourth international conference on advances in electrical, electronics, information, communication and bio-informatics (AEEICB) (pp. 1-5). IEEE..

[11]. Gopavanitha, K., & Nagaraju, S. (2017, August). A low cost system for real time water quality monitoring and controlling using IoT. In 2017 International conference on energy, communication, data analytics and soft computing (ICECDS) (pp. 3227-3229). IEEE..

[12]. Poornisha, K., Keerthana, M. R., & Sumathi, S. (2018, February). Borewell water quality and motor monitoring based on IoT gateway. In 2018 International Conference on Communication, Computing and Internet of Things (IC3IoT) (pp. 514-518). IEEE.

[13]. Soni, K., Waghela, D., Shah, R., & Mohan, M. (2018, January). Smart well monitoring system. In 2018 International Conference on Smart City and Emerging Technology (ICSCET) (pp. 1-5). IEEE.

[14]. Das, B., & Jain, P. C. (2017, July). Real-time water quality monitoring system using Internet of Things. In 2017 International conference on computer, communications and electronics (Comptelix) (pp. 78-82). IEEE.

[15]. Menon, G. S., Ramesh, M. V., & Divya, P. (2017, October). A low cost wireless sensor network for water quality monitoring in natural water bodies. In 2017 IEEE Global Humanitarian Technology Conference (GHTC) (pp. 1-8). IEEE.

[16]. Yauri, R., Rios, M., & Lezama, J. (2017, August). Water quality monitoring of Peruvian Amazon based in the Internet of Things. In 2017 IEEE XXIV International conference on electronics, electrical engineering and computing (INTERCON) (pp. 1-4). IEEE.

[17]. Raju, K. R. S. R., & Varma, G. H. K. (2017, January). Knowledge based real time monitoring system for aquaculture using IoT. In 2017 IEEE 7th international advance computing conference (IACC) (pp. 318-321). IEEE.

[18]. Kafli, N., & Isa, K. (2017, December). Internet of Things (IoT) for measuring and monitoring sensors data of water surface platform. In 2017 IEEE 7th International Conference on Underwater System Technology: theory and applications (USYS) (pp. 1-6). IEEE.

[19]. Ariffin, S. H., Baharuddin, M. A., Fauzi, M. H. M., Latiff, N. M., Syed-Yusof, S. K., & Latiff, N. A. (2017, November). Wireless water quality cloud monitoring system with self-healing algorithm. In 2017 IEEE 13th Malaysia International Conference on Communications (MICC) (pp. 218-223).

IEEE.

[20]. Encinas, C., Ruiz, E., Cortez, J., & Espinoza, A. (2017, April). Design and implementation of a distributed IoT system for the monitoring of water quality in aquaculture. In 2017 Wireless telecommunications symposium (WTS) (pp. 1-7). IEEE.

[21]. Koditala, N. K., & Pandey, P. S. (2018, August). Water quality monitoring system using IoT and machine learning. In 2018 International Conference on Research in Intelligent and Computing in Engineering (RICE) (pp. 1-5). IEEE.

[22]. P. M. Pujar, H. H. Kenchannavar, and U. P. Kulkarni, “Water quality assessment and monitoring for river Malaprabha using the Internet of Things (IoT) system,” Int. J. Recent Technol. Eng., vol. 8, no. 2, pp. 3839–3844, 2019, doi: 10.35940/ijrte.B2466.078219.

[23]. Gupta, A., Mishra, S., Bokde, N., & Kulat, K. (2016). Need of smart water systems in India. International Journal of Applied gineering Research, 11(4), 2216-2223.

[24]. Shahanas, K. M., & Sivakumar, P. B. (2016). Framework for a smart water management system in the context of smart city initiatives in India. Procedia Computer Science, 92, 142-147.

[25]. Kenchannavar, H. H., Pujar, P. M., Kulkarni, R. M., & Kulkarni, U. P. (2021). Evaluation and Analysis of Goodness of Fit for Water Quality Parameters Using Linear Regression Through the Internet-of-Things-Based Water Quality Monitoring System. IEEE Internet of Things Journal, 9(16), 14400-14407.

[26]. https://www.sciencedirect.com/topics/earth-and-planetary-sciences/wastewater-management