OPEN ACCESS

Ind. Jr. of Mod. Res. and Rev *PEER-REVIEWED JOURNAL* *Volume 4 Issue 2 [Feb] Year 2026*

Indian Journal of Modern Research and Reviews

This Journal is a member of the *'Committee on Publication Ethics'*

Online ISSN:2584-184X

Research Article

A Systematic Review of IoT-Enabled Smart Water Monitoring Systems for Sustainable Water Management

Lavina Wilson Dsouza [1*], Sanika Sanjay Kamble [2]

[1] Dept, of Electronics and Telecommunication Engineering, Sant Gajanan Maharaj College of Engineering Kolhapur, Maharashtra, India

[2] Dept, of Electronics and Telecommunication Engineering. Sant Gajanan Maharaj College of Engineering Kolhapur, Maharashtra, India

Corresponding Author: Lavina Dsouza*

DOI: https://doi.org/10.5281/zenodo.18464599

Abstract

Ensuring continuous access to safe and clean water has become a critical global challenge due to rapid urbanisation, industrial expansion, and environmental degradation. Conventional water quality monitoring approaches rely on manual sampling and laboratory analysis, resulting in delayed responses and limited spatial coverage. Recent advancements in the Internet of Things (IoT) have enabled the development of smart water monitoring systems capable of real-time sensing, remote data transmission, and intelligent analysis.

This paper presents a systematic review of IoT-based smart water monitoring systems with emphasis on sensing technologies, communication architectures, data processing strategies, and system scalability. Existing research demonstrates that IoT-enabled solutions significantly enhance monitoring efficiency, reduce operational costs, and support data-driven decision-making. However, challenges related to energy efficiency, data reliability, scalability, and intelligent analytics remain open research issues. By critically analysing existing studies, this review identifies research gaps and highlights future directions for sustainable and intelligent water monitoring infrastructures.

Manuscript Information

- **ISSN No:** 2584-184X
- **Received:** 26-12-2025
- **Accepted:** 23-01-2025
- **Published:** 03-02-2026
- **MRR:**4(2); 2026: 13-16
- **©2026, All Rights Reserved**
- **Plagiarism Checked:** Yes
- **Peer Review Process:** Yes

How to Cite this Article

Dsouza W L, Kamble S S. A Systematic Review of IoT-Enabled Smart Water Monitoring Systems for Sustainable Water Management. Indian J Mod Res Rev. 2026;4(2):13-16.

Access this Article Online

www.multiarticlesjournal.com

KEYWORDS: Internet of Things, Smart Water Monitoring, Water Quality Assessment, Wireless Sensor Networks, Sustainable Water Management

1. INTRODUCTION

Water quality monitoring plays a vital role in public health protection, environmental sustainability, and smart city development. Increasing contamination of surface and groundwater resources has intensified the need for continuous and automated monitoring solutions. Traditional water monitoring systems are limited by manual intervention, low sampling frequency, and delayed analysis, which restricts their effectiveness in early contamination detection.

The Internet of Things (IoT) paradigm has emerged as a transformative technology by enabling interconnected sensing devices, wireless communication, and cloud-based analytics. IoT-based water monitoring systems facilitate real-time data acquisition, remote accessibility, and scalable deployment across diverse environments. Surveys on IoT technologies emphasise their applicability in environmental monitoring due to flexibility, interoperability, and cost efficiency [1], [15]. Wireless sensor networks (WSNs) further enhance spatial coverage and autonomous operation for large water bodies [2].

Despite significant progress, existing IoT-based water monitoring solutions exhibit limitations related to sensor reliability, energy consumption, data security, and intelligent decision-making. This review critically examines recent IoT-enabled water monitoring systems to provide insights into current trends, challenges, and future research opportunities.

2. SYSTEMATIC REVIEW METHODOLOGY

This review follows a systematic literature review methodology to identify, analyse, and classify IoT-enabled smart water monitoring systems. Major scientific databases, including IEEE Xplore, Scopus, SpringerLink, Elsevier ScienceDirect, and Google Scholar, were explored to collect relevant research articles.

The search was conducted using combinations of keywords such as "IoT-based water monitoring," "smart water quality monitoring," "wireless sensor networks for water," "LoRa water monitoring," and "machine learning for water quality assessment."

Inclusion criteria consisted of peer-reviewed journal articles and conference papers published between 2014 and 2024, focusing on IoT-enabled real-time water monitoring systems. Exclusion criteria included non-IoT-based studies, simulation-only works, and articles lacking experimental validation.

A total of more than 70 articles were initially identified, out of which 15 highly relevant and frequently cited studies were selected for in-depth analysis. The selected studies were classified based on system architecture, sensing technologies, communication methods, data analytics, and application domain.

3. IoT Technologies for Water Monitoring:

IoT-based water monitoring systems typically consist of four layers:

1. Sensing Layer: Includes physical and chemical sensors to capture water quality parameters.
2. Communication Layer: Provides wireless connectivity through Wi-Fi, GSM, NB-IoT, LoRaWAN, or ZigBee.
3. Data Processing Layer: Employs edge computing and cloud platforms for analysis, storage, and visualization.
4. Application Layer: Enables monitoring dashboards, alerts, and decision support systems.

Wireless sensor networks (WSNs) are widely adopted due to low power consumption and scalability. Edge-assisted architectures reduce latency and network congestion by processing data locally before transmitting to the cloud [4], [14]. Low-power wide-area networks such as LoRaWAN enable long-range communication with minimal energy consumption [5], [6].

4. Water Quality Parameters and Sensor Technologies:

Critical water quality parameters include pH, turbidity, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), temperature, oxidation-reduction potential (ORP), nitrates, and ammonia.

- Electrochemical sensors: Used for pH, DO, and EC.
- Optical sensors: Used for turbidity and colour.
- Temperature sensors: Ensure measurement compensation.
- MEMS-based sensors: Compact and low-power for IoT deployment.

Challenges include sensor calibration drift, fouling, and long-term stability. Regular maintenance and sensor fusion are recommended for reliable measurements.

5. Communication Technologies and Protocols:

IoT water monitoring systems use multiple communication technologies:

- Short-range: Wi-Fi, ZigBee
- Cellular: GSM, NB-IoT
- Long-range, low-power: LoRaWAN

Protocol selection depends on range, bandwidth, energy, and application needs. MQTT and CoAP are commonly used for lightweight, reliable data transmission.

6. Data Processing, Edge, and Cloud Analytics:

- Cloud computing: Provides scalable storage, visualisation, and analytics.
- Edge computing: Processes data locally, reducing latency and network load.
- Hybrid edge-cloud systems: Combine real-time decision-making with long-term analytics for reliable operation [4], [14].

7. LITERATURE REVIEW

The literature shows multiple approaches to IoT-enabled water monitoring:

Postolache et al. (2014) [2] proposed a wireless sensor network (WSN)–based water quality monitoring framework designed for real-time environmental assessment. The system integrates multiple water quality sensors connected through low-power sensor nodes, enabling continuous data acquisition and remote monitoring. While the framework demonstrated improved monitoring efficiency and spatial coverage, it suffered from limited node lifetime due to battery constraints and lacked advanced data analytics for intelligent decision-making.

Bhardwaj et al. (2018) [3] developed a cyber–physical system (CPS) incorporating soft computing techniques for multi-sensor water quality assessment. The system employed fuzzy logic and intelligent data fusion to enhance accuracy in water quality classification. Despite improved assessment reliability, the approach introduced high computational complexity and required frequent sensor calibration, making large-scale deployment challenging.

Nasir et al. (2019) [4] presented an edge computing–assisted IoT framework aimed at reducing latency and bandwidth consumption in water quality monitoring systems. By processing sensor data at edge nodes before cloud transmission, the system achieved faster response times and improved network efficiency. However, the framework faced challenges related to edge resource management, hardware cost, and scalability, particularly in dense sensor deployments.

Codeluppi et al. (2020) [5] implemented a LoRaWAN-based IoT water monitoring system suitable for large-area and remote deployments. The use of LoRaWAN enabled long-range communication with low power consumption, making it ideal for rural and distributed water sources. Nevertheless, the system was constrained by low data transmission rates and limited support for high-frequency sensing, which may affect real-time monitoring requirements.

Sutar and Shirsat (2021) [6] proposed a LoRa-based low-power water quality monitoring system emphasising energy efficiency and long-term operation. The system demonstrated extended battery life and stable communication over long distances. However, similar to other LoRa-based approaches, it suffered from restricted throughput and limited scalability when multiple nodes transmit simultaneously.

Islam et al. (2021) [7] introduced an IoT-enabled water quality monitoring system integrated with machine learning algorithms for predictive analysis. Sensor data were processed using supervised learning models to forecast water quality trends and detect anomalies. While the approach enhanced predictive capability, its performance depended heavily on data quality, model training time, and computational resources, limiting its applicability in resource-constrained environments.

Al-Shamiri et al. (2021) [13] developed an IoT-based continuous water quality assessment system utilising real-time sensor data and cloud-based analysis. The system improved accessibility and monitoring continuity through web-based dashboards. However, it relied extensively on stable internet connectivity and exhibited sensor drift issues, necessitating regular maintenance and recalibration.

8. Comparative Analysis of Existing Systems:

A comparative evaluation of the reviewed studies is highlighted in Table I, presenting the key differences in adopted sensing technologies, communication methods, scalability considerations, and identified system limitations. This comparison enables a structured assessment of existing IoT-based smart water monitoring solutions and facilitates the identification of strengths, weaknesses, and research gaps across different system designs.

Table I: Comparative Analysis of IoT-Based Smart Water Monitoring Systems

Ref.	Monitoring Approach	Communication	Key Contribution	Limitations
Postolache et al. (2014) [2]	WSN-based	WSN	Large-area coverage	Energy constraints
Bhardwaj et al. (2018) [3]	Cyber–physical	IoT	Improved decision accuracy	Computational complexity
Nasir et al. (2019) [4]	Edge-assisted IoT	IoT+Edge	Reduced latency	Edge resource management
Codeluppi et al. (2020) [5]	LoRaWAN-based	LoRaWAN	Long-range, low power	Low data rate
Sutar and Shirsat (2021) [6]	LoRa-based	LoRa	Energy-efficient	Limited throughput
Islam et al. (2021) [7]	IoT+ML prediction	Cloud IoT	Predictive analytics	Model training overhead
Al-Shamiri et al. (2021) [13]	IoT assessment system	IoT	Continuous assessment	Sensor calibration

Observations:

- IoT enhances monitoring capabilities
- No single approach fully addresses scalability, energy efficiency, and predictive analytics simultaneously

9. Research Challenges and Open Issues:

Despite advancements, several challenges persist in IoT-based smart water monitoring systems. Sensor degradation and calibration issues affect long-term reliability [3], [13]. Energy-efficient communication remains a key concern for large-scale deployments [5], [6]. Cloud-dependent systems face latency and connectivity limitations, particularly in remote regions [11]. Security, data integrity, and machine learning model generalisation remain open research problems.

10. Future Research Directions:

Future research should focus on hybrid architectures integrating edge computing, cloud analytics, and low-power communication technologies. Adaptive machine learning models can enhance predictive accuracy while reducing computational overhead. Standardisation of IoT architectures and protocols is essential to improve interoperability, security, and scalability. Alignment of smart water monitoring systems with sustainable development goals can further support intelligent urban and rural water management strategies.

11. CONCLUSION

This systematic review analysed IoT-enabled smart water monitoring systems, emphasising sensing technologies, communication frameworks, data processing strategies, and sustainability aspects. IoT-based solutions significantly improve real-time monitoring, decision-making, and scalability compared to traditional methods. However, challenges remain in energy efficiency, sensor reliability, data integrity, and intelligent analytics. Addressing these challenges through integrated and standardised architectures is critical for developing sustainable and intelligent water monitoring infrastructures.

ACKNOWLEDGMENT

The authors would like to acknowledge the academic guidance and support provided by the Department of Electronics and Telecommunication Engineering, Sant Gajanan Maharaj College of Engineering, during the preparation of this review paper.

REFERENCES

1. Al-Fuqaha A, Guizani M, Mohammadi M, Aledhari M, Ayyash M. Internet of Things: A survey on enabling technologies, protocols, and applications. **IEEE Commun Surv Tutor.** 2015;17(4):2347–2376. doi:10.1109/COMST.2015.2444095
2. Postolache O, Pereira JM, Girão P. Water quality monitoring and analysis based on wireless sensor networks. **Measurement.** 2014;58:236–246. doi:10.1016/j.measurement.2014.08.013
3. Bhardwaj J, Gupta KK, Gupta R. Towards a cyber–physical era: Soft computing framework based multi-sensor array for water quality monitoring. **Appl Soft Comput.** 2018;72:650–660. doi:10.1016/j.asoc.2018.08.027
4. Nasir Q, Qasse IA, Talib MA, Nassif AB. Performance analysis of edge computing for IoT-based water quality monitoring. **IEEE Access.** 2019;7:155447–155463. doi:10.1109/ACCESS.2019.2949268
5. Codeluppi G, Cilfone A, Davoli L, Ferrari G. LoRaWAN-based IoT smart water monitoring system. **IEEE Sens J.** 2020;20(2):1082–1094. doi:10.1109/JSEN.2019.2947292
6. Sutar P, Shirsat A. LoRa-based smart water quality monitoring system. **Int J Comput Appl.** 2021;174(24):1–6.
7. Islam MS, et al. Water quality prediction using machine learning and IoT sensors. **Sustain Comput Inform Syst.** 2021;30:100470. doi:10.1016/j.suscom.2021.100470
8. Khatri A, Vairavamoorthy K. Challenges for urban water quality management in smart cities. **Water.** 2019;11(5):1017. doi:10.3390/w11051017
9. Ayaz M, Ammad-Uddin M, Sharif Z, Mansour A, Aggoune EHM. Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk. **IEEE Access.** 2019;7:129551–129583. doi:10.1109/ACCESS.2019.2932609
10. Perumal T, Sulaiman MN, Leong CY. Internet of Things (IoT) enabled water monitoring system. In: **Proc IEEE 4th Global Conf Consumer Electronics (GCCE);** 2015. p. 86–87. doi:10.1109/GCCE.2015.7398639
11. Koduru SR, Babu SR, Reddy KR. IoT-based water quality monitoring system using cloud computing. **Int J Eng Res Technol.** 2020;9(6):420–424.
12. Kumar R, Rajasekaran P, Rajkumar S. Real-time water quality monitoring using IoT sensor networks. **Environ Monit Assess.** 2020;192(8):1–12. doi:10.1007/s10661-020-08439-3
13. Al-Shamiri MH, et al. IoT-based smart water quality monitoring and assessment system. **J Water Process Eng.** 2021;40:101833. doi:10.1016/j.jwpe.2021.101833
14. Li S, Wang Y, Zhang H. Edge-assisted IoT-based water quality monitoring system. **Future Gener Comput Syst.** 2021;123:43–52. doi:10.1016/j.future.2021.04.010
15. Zanella A, Bui N, Castellani A, Vangelista L, Zorzi M. Internet of Things for smart cities. **IEEE Internet Things J.** 2014;1(1):22–32. doi:10.1109/JIOT.2014.2306328

About the corresponding author

Lavina Wilson Dsouza is affiliated with the Department of Electronics and Telecommunication Engineering at Sant Gajanan Maharaj College of Engineering, Kolhapur, Maharashtra, India. Her academic interests include communication systems, signal processing, and emerging technologies in electronics engineering, with a focus on teaching, research, and technical innovation.