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IoT-Driven Water Quality Monitoring Systems for Smart Cities

Suvam Behera*

School of Computer Science Engineering, KIIT University, Bhubaneswar, India; 22052690@kiit.ac.in.

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Abstract

Water quality monitoring systems in smart cities, driven by the Internet of Things (IoT), utilize interconnected sensors to continuously measure parameters such as pH, turbidity, and contaminants. These systems offer real-time data and analysis, making it possible to quickly identify problems like contamination or leaks. By incorporating machine learning, they aid in forecasting trends and enhancing resource management. The architecture of the system consists of sensing, communication, and data processing layers, with wireless protocols used to transmit information for analysis. These systems enhance urban water management, promote sustainable development, and efficiently address water quality challenges.

Keywords: Predictive analytics, Resource optimization, Cloud computing, Environmental monitoring.

1 | Introduction

As urban populations grow and cities become increasingly complex, ensuring access to clean and safe water has become a pressing challenge. Water quality is critical for public health, environmental sustainability, and economic development, especially in smart cities. These cities leverage advanced technologies to create interconnected, intelligent systems that enhance the quality of life for their residents. Among these technologies, the Internet of Things (IoT) has emerged as a game-changer for real-time monitoring and management of urban infrastructure, including water distribution systems. IoT-driven water quality monitoring systems enable continuous, automated tracking of essential water parameters such as pH, turbidity, temperature, and contaminant levels [1], [2]. By deploying a network of sensors throughout the water supply chain, from reservoirs and pipelines to treatment plants, IoT technology allows city authorities to monitor water quality remotely and respond quickly to any anomalies [3], [4]. This real-time monitoring ensures compliance with regulatory standards and reduces the risks associated with water contamination or system failures [5]. This paper will explore the architecture, implementation, and benefits of IoT-based water

Corresponding Author: 22052690@kiit.ac.in

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quality monitoring systems in smart cities. We will also discuss the challenges of deploying such systems, including data security concerns, sensor maintenance, and the need for a robust communication infrastructure to support IoT networks [6], [7].

2 | Figures and Tables

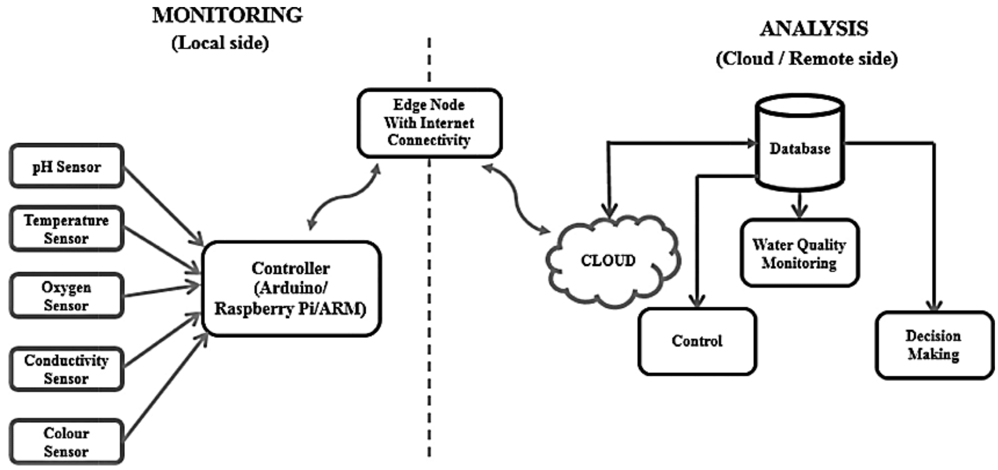

Fig. 1. Internet of things-driven water quality monitoring system architecture [8].

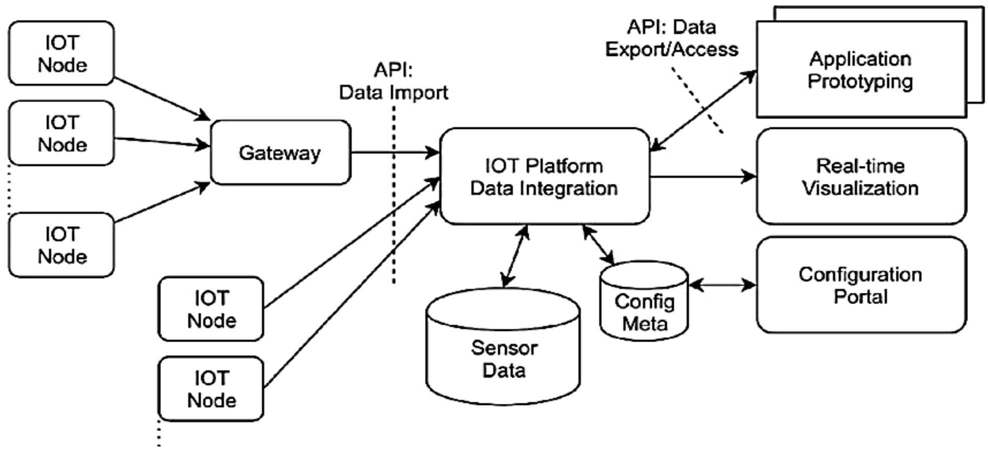

Fig. 2. Sensor data and internet of things platform data integration.

Table 1. List of water quality monitoring system architecture [9], [10].

Layer	Component	Description	Function
Sensor layer	pH sensor	Measures the acidity or alkalinity of water in reservoirs, pipelines, and treatment plants.	Tracks pH levels to ensure water quality standards are met.
	Turbidity sensor	Measures water clarity by detecting suspended particles.	Monitors water clarity to detect contamination or inefficiencies in water treatment.

Table 1. Continued.

Layer	Component	Description	Function
	Temperature sensor	Measures the temperature of water in different parts of the water distribution system.	Ensures water remains within optimal temperature ranges for quality and biological safety.
	Dissolved Oxygen (DO) sensor	Measures the oxygen levels in water, critical for aquatic life and water quality.	Ensures the water has sufficient oxygen levels to support life and prevent contamination.
	Conductivity sensor	Measures the electrical conductivity of water to detect dissolved salts and contaminants.	Helps identify pollution or changes in water mineral content.
Communication layer	LoRaWAN	Long-range, low-power wireless protocol used for data transmission from remote sensors.	Transmits sensor data over long distances with minimal power consumption.
	Zigbee	Short-range, low-power wireless protocol ideal for sensor data transmission in localized environments.	Connects nearby sensors to gateways or the cloud for real-time monitoring.
	NB-IoT	Narrowband IoT protocol that enables efficient, low-bandwich communication for urban water networks.	Optimized for transmitting data across urban areas with high sensor density.
Cloud layer	Cloud data processing	Cloud-based infrastructure that processes incoming sensor data, analyzes it, and stores it.	Enables real-time analytics, long-term storage, and decision-making based on water data.
	User interface	Dashboard or mobile application where users can view water quality metrics and alerts.	Allows stakeholders (city authorities, technicians) to monitor water quality and system status.

3 | Variables

Designing an IoT-driven water quality monitoring system architecture involves several components and variables to ensure effective data collection, processing, transmission, and analysis. Here's an outline of the key variables and equations that may be relevant.

3.1 | Sensors

Variables

I. TTT: Temperature (°C)

II. pH: pH level

III. DO: (mg/L)

IV. Turb: Turbidity (NTU)

V. EC: Electrical Conductivity (μS/cm)

VI. COD: Chemical Oxygen Demand (mg/L)

Sensor accuracy

A (Percentage)

3.2 | Data Transmission

Network variables

I. R: Data rate (bps)

II. D: Data packet size (bytes)

III. L: Latency (ms)

Transmission distance

Dtrans (Meters)

3.3 | Data Processing

Processing unit

P: Processing power (In FLOPS or MIPS)

Energy consumption

E (Joules)

3.4 | Storage

Storage capacity

S(GB)

Data retention period

Tret (Days)

3.5 | Power Supply

Battery life

Lb (Hours)

Power consumption

Pcons (mW)

3.6 | User Interface

User engagement

Ueng (Number of users)

Alerts/notifications

N(Number of alerts)

4 | Equations

Data collection rate

$$R_{collection} = F_s \times N_s,$$

whrere F_s is the frequency of sampling (Samples per second), and N_s is the number of sensors.

Data transmission time

$$T_{trans} = \frac{D}{R},$$

where D is the data packet size and R is the data rate.

Energy consumption

$$E = P_{cons} \times T_{usage},$$

where T_{usage} is the total active time of the devise.

Battery life

$$L_b = \frac{C}{P_{cons}},$$

where C is the battery capacity (In mAh).

Data storage needs

$$S_{needed} = R_{collection} \times T_{ret},$$

where $R_{collection}$ is the rate of data collection and T_{ret} is the retention period in seconds.

Water Quality Index (WQI)

A composite index calculated from various parameters:

$$WQI = \sum_{i=1}^{n} w_i . v_i,$$

where w_i is the weight of each parameter (Determined based on its importance), and v_i is the normalized value of each parameter.

5 | Concussion

Implementing IoT-driven water quality monitoring systems offers significant advancements in managing water resources for smart cities. Integrating real-time data collection, edge computing, and cloud-based analytics enables proactive water quality management, ensuring the safety and sustainability of urban water supplies.

This approach allows for continuous monitoring, early detection of contamination, and prompt decision-making, reducing the risks associated with polluted water and contributing to urban populations' overall health and well-being. Furthermore, IoT in such applications enhances operational efficiency, reduces manual intervention, and offers cost-effective solutions for municipal water management.

As cities grow, scaling IoT-driven water monitoring solutions will become increasingly critical for addressing water scarcity, pollution, and infrastructure challenges. Future research could focus on improving sensor accuracy, expanding the scope of parameters monitored, and integrating machine learning to predict potential issues before they arise.

In conclusion, IoT-based water quality monitoring systems are pivotal to the development of smart, sustainable cities. They provide valuable insights for decision-makers and contribute to the efficient, safe management of vital water resources.

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Author Contributaion

Suvam Behera: Conceptualization of the study and writing the original draft, overall project administration, final editing of the manuscript, implementation of algorithm.

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Data Availability

The data used and analyzed during the current study are available from Suvam Behera upon reasonable request.

Conflicts of Interest

The author declare no conflicts of interest regarding the publication of this paper.

If necessary, these sections should be tailored to reflect the specific details and contributions.

References

[1] Priya, M. D. (2021). Smart water quality monitoring system using IoT. *CVR journal of science and technology*, *21*(1), 31–38. https://www.cvr.ac.in/ojs/index.php/cvracin/article/view/736

[2] de Paula, H. T. L., Gomes, J. B. A., Affonso, L. F. T., Rabelo, R. A. L., & Rodrigues, J. J. P. C. (2019). An IoT-based water monitoring system for smart buildings. *2019 IEEE international conference on communications workshops (ICC workshops)* (pp. 1–5). IEEE. https://doi.org/10.1109/ICCW.2019.8756905

[3] Mohapatra, H., & Rath, A. K. (2020). IoT-based smart water. In *IoT technologies in smart cities: From sensors to big data, security and trust* (pp. 63–82). Institution of engineering and technology. http://dx.doi.org/10.1049/PBCE128E

[4] Hemdan, E. E. D., Essa, Y. M., Shouman, M., El-Sayed, A., & Moustafa, A. N. (2023). An efficient IoT based smart water quality monitoring system. *Multimedia tools and applications*, *82*(19), 28827–28851. https://doi.org/10.1007/s11042-023-14504-z

[5] Mohapatra, H., & Rath, A. K. (2019). Detection and avoidance of water loss through municipality taps in India by using smart taps and ICT. *Institution of engineering and technology wireless sensor systems*, *9*(6), 447–457. https://doi.org/10.1049/iet-wss.2019.0081

[6] Jan, F., Min-Allah, N., & Düştegör, D. (2021). IoT based smart water quality monitoring: Recent techniques, trends and challenges for domestic applications. *Water*, *13*(13), 1729. https://doi.org/10.3390/w13131729

[7] Rathi, S., & Gola, V. K. (2024). Innovative components of smart cities with a special focus of water distribution systems challenges and opportunities: A review. *IOP conference series: Earth and environmental science* (pp. 12146). Institute of physics publishing. http://doi.org/10.1088/1755-1315/1326/1/012146

[8] Hynes, R., Jagatheesaperumal, S., Kamyab, H., Jesudoss, A. J. S., Al-Khashman, O., Kuslu, Y., … ., & Suresh, B. (2020). Modern enabling techniques and adsorbents based dye removal with sustainability concerns in textile industrial sector -A comprehensive review. *Journal of cleaner production*, *272*, 122636. http://dx.doi.org/10.1016/j.jclepro.2020.122636

[9] Chen, S. L., Chou, H. S., Huang, C. H., Chen, C. Y., Li, L. Y., Huang, C. H., … ., & Huang, J. S. (2023). An intelligent water monitoring IoT system for ecological environment and smart cities. *Sensors*, *23*(20), 8540. https://doi.org/10.3390/s23208540

[10] Chen, Y., & Han, D. (2018). Water quality monitoring in smart city: A pilot project. *Automation in construction*, *89*, 307–316. https://doi.org/10.1016/j.autcon.2018.02.008