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AI-Driven Predictive Modeling for Real-Time Water Quality Monitoring in Urban Water Supply Systems

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ABSTRACT

Ensuring safe and reliable urban water supply is a critical challenge globally, exacerbated by increasing urbanization, climate change, and aging infrastructure. Traditional water quality monitoring methods often involve manual sampling and laboratory analysis, which are time-consuming, resource-intensive, and provide only retrospective insights, hindering proactive management of contamination events. The advent of artificial intelligence (AI) and the Internet of Things (IoT) has revolutionized the field, enabling real-time, continuous monitoring and predictive modeling of water quality. This review paper explores the significant advancements in AI-driven predictive modeling for urban water supply systems. It delves into diverse AI techniques, including machine learning, deep learning, and hybrid models, employed to process vast datasets from IoT sensors, offering insights into parameters like pH, turbidity, dissolved oxygen, and conductivity. The paper highlights how these models can accurately forecast water quality parameters, detect anomalies, identify potential contamination sources, and optimize treatment processes. Furthermore, it discusses the benefits of such systems in enhancing operational efficiency, reducing health risks, and promoting sustainable water management. The integration of these technologies represents a paradigm shift towards intelligent water networks, empowering water utilities with unprecedented capabilities for real-time decision-making and rapid response to water quality fluctuations, ultimately safeguarding public health and ensuring the integrity of urban water resources.

Keywords : AI-driven, Predictive Modeling, Water Quality, Real-Time Monitoring, Urban Water Supply

I. INTRODUCTION

Water is an indispensable resource for human sustenance and socio-economic development. However, the quality of urban water supply systems is increasingly threatened by various factors, including industrial discharge, agricultural runoff, aging infrastructure, and climate change impacts. Historically, water quality monitoring relied heavily on manual sampling and laboratory analysis, a process that, while accurate, suffered from inherent delays. This reactive approach often meant that contamination events were detected only after they had already impacted consumers, leading to potential health risks and significant economic losses. The need for a proactive, real-time monitoring and management strategy became evident as urban populations burgeoned and the complexity of water distribution networks increased.

The late 20th and early 21st centuries witnessed a paradigm shift with the emergence of advanced sensor technologies and the Internet of Things (IoT). These innovations enabled the deployment of pervasive networks of sensors capable of continuously collecting diverse water quality parameters, such as pH, dissolved oxygen, turbidity, conductivity, and temperature, directly within the distribution system. This unprecedented influx of real-time data, however, presented a new challenge: how to effectively process, analyze, and derive actionable insights from such voluminous and dynamic datasets. This is where Artificial Intelligence (AI) has emerged as a transformative force, providing the analytical power to interpret complex patterns, predict future states, and identify anomalies in water quality.

Despite the significant strides made, several research gaps persist in the complete realization of AI-driven predictive modeling for urban water supply systems. One major gap lies in the development of robust and generalizable AI models that can effectively adapt to the inherent variability and non-linearity of water quality data across diverse urban environments. Furthermore, integrating heterogeneous data sources, including sensor data, meteorological information, demographic data, and even social media feeds, remains a complex challenge. The interpretability and explainability of complex AI models, particularly deep learning architectures, are also crucial for gaining trust and facilitating effective decision-making by water utility operators. Finally, the scalability and cost-effectiveness of deploying comprehensive AI-driven monitoring systems across large-scale urban water networks require further research and development.

The aim of this review paper is to comprehensively analyze the current state-of-the-art in AI-driven predictive modeling for real-time water quality monitoring in urban water supply systems. This includes examining the various AI algorithms and methodologies employed, their applications, and their effectiveness in addressing the challenges of water quality management. The objective is to synthesize existing knowledge, identify key advancements, highlight emerging trends, and shed light on the remaining research gaps and future directions in this rapidly evolving field. By providing a structured overview of the literature, this paper seeks to serve as a valuable resource for researchers, engineers, and policymakers involved in ensuring the safety and sustainability of urban water resources.

II. Literature Study

In [1] S. Shams et al. describe a comprehensive risk assessment framework for urban water supply systems in tropical climates. Their work addresses the unique vulnerabilities of these systems, including potential impacts from extreme weather events and rapid urbanization. They highlight the importance of understanding the intricate interdependencies within the water supply chain to develop resilient strategies. The authors emphasize that traditional risk assessment methodologies often fall short in capturing the dynamic and complex nature of urban water systems, particularly under changing climatic conditions. Their research aims to provide a more holistic approach, considering a wide range of factors from source water quality to distribution network integrity, and proposing mitigation measures to enhance system robustness against various threats, ultimately contributing to more secure and sustainable water provision in urban tropical environments.

In [2] J. Wang et al. describe a simulation-based optimization approach for urban water storage tank operations. Their research focuses on striking a delicate balance between maintaining hydraulic stability, ensuring optimal water quality, and achieving energy conservation within the water distribution network. The authors highlight that traditional tank operation strategies often prioritize one aspect over others, leading to inefficiencies or compromises in system performance. Their methodology leverages advanced simulation techniques to explore various operational scenarios and identify optimal control policies that can simultaneously satisfy multiple conflicting objectives. This integrated approach not only improves the overall efficiency and reliability of urban water supply but also contributes to significant reductions in operational costs and environmental impact, demonstrating a holistic approach to water infrastructure management.

In [3] Y.-Q. Wang et al. describe the application of Transformer Networks and a novel loss function with punishment for optimized management of urban water supply systems. This paper delves into the use of advanced deep learning architectures, specifically Transformers, which are well-suited for processing sequential data like time-series water quality parameters. The proposed loss function, incorporating a punishment mechanism, aims to enhance the model's ability to identify and respond to critical water quality deviations, even in the presence of noise or sparse data. Their research demonstrates how these sophisticated AI models can lead to more accurate predictions and proactive management decisions, moving beyond traditional statistical or simpler machine learning approaches. The findings suggest a significant step towards more intelligent and responsive urban water infrastructure.

In [4] P. Verma and P. Mehta describe emerging trends in real-time water quality monitoring and sanitation systems. This paper provides a broad overview of the technological advancements that are reshaping how water quality is assessed and managed. They highlight the shift from periodic, manual sampling to continuous, automated monitoring facilitated by IoT sensors and big data analytics. The authors also discuss the increasing integration of AI and machine learning for predictive modeling and anomaly detection, which are crucial for proactive intervention. Furthermore, they touch upon innovations in sanitation systems that complement these monitoring efforts, aiming for a more holistic approach to urban water management. Their work underscores the growing importance of smart technologies in addressing the complexities of water quality in an increasingly urbanized world.

In [5] N. Chavhan et al. describe APAH, an autonomous IoT-driven real-time monitoring system specifically designed for industrial wastewater. This research emphasizes the critical need for continuous and accurate monitoring in industrial settings to prevent pollution and ensure compliance with environmental regulations. APAH leverages a network of IoT sensors to collect real-time data on various wastewater parameters, which is then processed autonomously to detect anomalies and potential violations. The system's autonomous nature minimizes human intervention and provides immediate alerts, enabling rapid corrective actions. This work showcases a practical application of IoT technology for environmental protection, demonstrating its potential to significantly improve the management and treatment of industrial effluents, thereby mitigating their ecological impact.

In [6] S. Banerjee describes the role of AI in monitoring and improving air and water quality for green innovation. This chapter within a larger publication highlights how AI is becoming an indispensable tool in environmental management and the pursuit of sustainable practices. Banerjee discusses how AI algorithms can analyze vast datasets from various sources, including sensor networks and satellite imagery, to identify pollution sources, predict environmental trends, and optimize resource allocation for green initiatives. The focus is on how AI can enable smarter decision-making and more effective interventions to reduce environmental impact and foster a more sustainable future. This work emphasizes the cross-cutting nature of AI in environmental science, extending its impact beyond just water quality to broader ecological concerns.

In [7] X. Zhou and L. Huang describe smart water treatment systems as the future of environmental water management. Their paper explores how the integration of advanced technologies, particularly AI and IoT, is transforming traditional water treatment processes. They discuss how real-time data acquisition from sensors, coupled with AI-driven analytics, can optimize chemical dosing, predict equipment failures, and enhance overall treatment efficiency. The authors emphasize that smart systems can adapt dynamically to changing raw water quality and demand, leading to more sustainable and cost-effective operations. This work presents a compelling vision of how technological innovation can revolutionize water purification, ensuring the provision of safe drinking water while minimizing environmental footprint.

In [8] A. A. Abu Bakar et al. describe an IoT-based real-time water quality monitoring system with a focus on enhanced accuracy and reliability through sensor calibration. Their research highlights a crucial aspect of real-time monitoring: ensuring the trustworthiness of the data. They emphasize that while IoT sensors offer continuous data streams, their accuracy can drift over time. Their proposed system incorporates mechanisms for regular sensor calibration, either remotely or through automated procedures, to maintain high data fidelity. This ensures that the predictive models built upon this data are robust and reliable, leading to more accurate water quality assessments and more confident decision-making for water utilities. Their work underscores the importance of data quality in the successful deployment of IoT solutions in critical infrastructure.

In [9] Y. Kim et al. describe a stormwater digital twin with online quality control, designed to detect urban flood hazards under uncertainty. This innovative approach integrates real-time data with a virtual model of the stormwater system, allowing for dynamic simulation and prediction of flood risks. The "online quality control" aspect refers to the continuous validation and refinement of the digital twin using live sensor data, ensuring its accuracy and predictive power. This research is significant for urban planning and disaster management, as it provides a powerful tool for proactive flood mitigation and infrastructure resilience in the face of unpredictable weather events. The digital twin concept offers a comprehensive and dynamic view of urban water systems, extending beyond just quality monitoring to encompass hydraulic and flood management.

In [10] K. Angassa et al. describe the modeling of residual chlorine in the drinking water distribution system of Bishoftu Town, Ethiopia. This research focuses on a critical aspect of water quality management: ensuring adequate disinfection throughout the network. Residual chlorine is a key indicator of disinfection effectiveness and can degrade over time and distance in the distribution system. Their work uses modeling techniques to predict chlorine decay, helping water utilities optimize dosing strategies and identify areas where re-chlorination might be necessary. This is crucial for preventing waterborne diseases and maintaining public health, particularly in developing regions where resources for extensive real-time monitoring might be limited.

In [11] R. Taiwo et al. describe the opportunities and challenges of generative artificial intelligence (AI) in water distribution networks. This paper explores a cutting-edge area of AI application, moving beyond traditional predictive models to examine how generative AI can be used for tasks like synthetic data generation, system design optimization, and even simulating complex network behaviors. While acknowledging the immense potential, the authors also discuss the associated challenges, such as data requirements, model complexity, and ethical considerations. This research points towards a future where AI not only analyzes existing data but can also proactively assist in designing, managing, and improving water infrastructure, opening new avenues for innovation in the water sector.

In [12] R. Baena-Navarro et al. describe the intelligent prediction and continuous monitoring of water quality in aquaculture through the integration of machine learning and the Internet of Things (IoT). This research highlights the application of AI and IoT beyond urban drinking water, demonstrating its value in a controlled environment like aquaculture, where water quality is paramount for aquatic life. The authors showcase how real-time sensor data, combined with machine learning models, can predict critical parameters, allowing for proactive adjustments to maintain optimal conditions. This leads to more sustainable and productive aquaculture practices, minimizing losses due to poor water quality and enhancing overall environmental stewardship.

In [13] S. Das et al. describe how AI and IoT are supporting sixth-generation sensing for water quality assessment to empower sustainable ecosystems. This paper envisions a future where advanced sensing technologies, augmented by AI and IoT, provide unprecedented capabilities for understanding and managing water resources. They discuss how the convergence of these technologies can lead to highly intelligent and adaptive monitoring systems that go beyond basic parameter measurement to provide holistic insights into ecosystem health. This work emphasizes the role of technology in achieving broader sustainability goals, highlighting the potential of AI and IoT to contribute to a more resilient and environmentally conscious future.

In [14] P. Hamel et al. describe lessons learned from the field regarding low-cost monitoring systems for urban water management. This practical paper addresses a significant barrier to widespread adoption of real-time monitoring: the cost. The authors share insights from real-world deployments, focusing on the effectiveness and challenges of implementing affordable sensor networks and data acquisition systems. They emphasize that while high-end solutions exist, there's a strong need for accessible and scalable technologies that can be deployed in diverse urban settings, particularly in resource-constrained regions. Their work provides valuable guidance for developing and deploying practical and economically viable water quality monitoring solutions.

In [15] R. Wiryasaputra et al. describe an IoT real-time potable water quality monitoring and prediction model based on a cloud computing architecture. This research focuses on the infrastructure and technological stack required to support robust real-time monitoring and prediction. They highlight the advantages of leveraging cloud computing for data storage, processing, and model deployment, enabling scalability and accessibility of the monitoring system. The integration of IoT sensors with cloud-based analytics allows for continuous data flow and real-time insights, demonstrating a practical and deployable solution for modern urban water management. Their work provides a blueprint for building reliable and scalable real-time water quality systems.

In [16] R. Mohanasundaram et al. describe water quality monitoring and control in urban areas in real-time via IoT and mobile applications. This paper emphasizes the user-centric aspect of modern water quality management. They highlight how mobile applications can serve as intuitive interfaces for citizens and utility operators to access real-time water quality data and receive alerts. This approach not only enhances transparency but also empowers stakeholders to participate in water quality management. The integration of IoT for data collection with mobile platforms for data dissemination and control represents a practical and accessible solution for improving urban water services.

In [17] Z. Li et al. describe real-time water quality prediction in water distribution networks using graph neural networks (GNNs) with sparse monitoring data. This research addresses a common challenge in real-world water networks: the scarcity of sensor deployment due to cost or logistical constraints. GNNs are particularly well-suited for analyzing interconnected systems like water distribution networks, even with limited sensor coverage. By leveraging the topological information of the network, GNNs can infer water quality at unmonitored locations, providing a more comprehensive understanding of the system's state. This innovative approach offers a promising solution for achieving widespread water quality awareness without the need for ubiquitous sensor deployment.

In [18] I. Essamlali et al. provide a comprehensive review of advances in machine learning and IoT for water quality monitoring. This paper offers a broad survey of the literature, synthesizing key developments and trends in the field. They cover a wide range of machine learning algorithms, from traditional regression models to advanced deep learning techniques, and their applications in water quality prediction, anomaly detection, and source identification. The review also discusses the foundational role of IoT in enabling real-time data acquisition. This comprehensive overview serves as an excellent resource for researchers and practitioners seeking to understand the landscape of AI and IoT applications in water quality management.

In [19] W. Luo et al. describe a hybrid deep learning model for predicting water quality in municipal water management systems. This research highlights the benefits of combining different deep learning architectures to leverage their respective strengths. Hybrid models often achieve superior performance by capturing diverse patterns and dependencies within complex water quality datasets. The authors demonstrate how their hybrid approach can lead to more accurate and robust predictions, essential for effective municipal water management. This work exemplifies the ongoing evolution of AI methodologies towards more sophisticated and powerful predictive capabilities in the water sector.

In [20] A. K. Kalyanam provides a comprehensive overview of water management and the role of IoT, particularly focusing on its industrial impact. While not exclusively on urban water supply, this paper touches upon the broader implications of IoT in managing water resources across various sectors. It emphasizes how IoT sensors and data analytics can lead to more efficient water usage, reduced waste, and improved environmental compliance in industrial processes. The work serves as a reminder that the principles of real-time monitoring and AI-driven insights are applicable across the entire water value chain, contributing to more sustainable water management practices beyond just potable water.

III. Comparative Study

TABLE I. COMPARATIVE STUDY

Ref No.	Method	Advantages	Limitations
[1]	Urban water supply risks assessment framework (tropical climate)	Comprehensive understanding of interdependencies; considers broad range of factors; proposes mitigation measures.	Traditional methodologies fall short in dynamic and complex systems.
[2]	Simulation-based optimization of urban water storage tank operations	Balances hydraulic stability, water quality, and energy conservation simultaneously; significant reductions in operational costs and environmental impact.	(Implicit) Complexity of simulation and optimization; requires accurate system models.
[3]	Transformer Networks and Loss with Punishment for optimized management	Uses advanced deep learning for sequential data; enhanced ability to identify and respond to critical deviations; effective with noise/sparse data.	(Implicit) Complexity of Transformer models; potential for high computational requirements.
[4]	Overview of emerging trends in real-time water quality monitoring and sanitation systems	Highlights shift to continuous, automated monitoring; discusses integration of AI/ML for proactive intervention; holistic approach to urban water management.	(Review paper, specific method not applicable as primary focus).
[5]	APAH: Autonomous IoT-driven real-time monitoring system for industrial wastewater	Autonomous operation minimizes human intervention; provides immediate alerts; improves environmental compliance.	Specific to industrial wastewater, may not be directly transferable to potable water systems without modification.
[6]	Role of AI in monitoring and improving air and water quality for green innovation	AI analyzes vast datasets for pollution sources, environmental trends, and resource optimization; enables smarter decision-making.	(Review/Conceptual paper, specific method not applicable as primary focus).
[7]	Smart water treatment systems leveraging AI and IoT	Optimizes chemical dosing; predicts equipment failures; enhances treatment efficiency; adapts dynamically to changing conditions.	(Conceptual paper, specific method not applicable as primary focus).
[8]	IoT-based real-time water quality monitoring with sensor calibration	Ensures high data fidelity and trustworthiness; maintains accuracy over time; leads to robust and reliable predictive models.	Requires regular calibration mechanisms, which can add complexity or maintenance overhead.
[9]	Stormwater digital twin with online quality	Integrates real-time data with virtual model for dynamic simulation; proactive	(Implicit) High computational demand for digital twin;

	control	flood mitigation; continuous validation of digital twin.	complexity of model development and data integration.
[10]	Residual Chlorine Modelling in Drinking Water Distribution System	Predicts chlorine decay; helps optimize dosing strategies; identifies areas for re-chlorination; crucial for public health.	Model accuracy dependent on input parameters and network specific conditions; may not fully capture dynamic disinfectant demand.
[11]	Opportunities and challenges of generative AI in water distribution networks	Explores advanced AI for synthetic data generation, system design, and complex behavior simulation; new avenues for innovation.	Significant data requirements; model complexity; ethical considerations; relatively nascent field.
[12]	Intelligent prediction and continuous monitoring of water quality in aquaculture	Predicts critical parameters for proactive adjustments; supports sustainable and productive aquaculture; minimizes losses.	Specific to aquaculture, may not be directly transferable to urban water supply challenges.
[13]	AI and IoT for sixth-generation sensing for water quality assessment	Provides holistic insights into ecosystem health; enables highly intelligent and adaptive monitoring systems; contributes to broader sustainability.	(Conceptual paper, specific method not applicable as primary focus).
[14]	Low-cost monitoring systems for urban water management	Addresses cost barriers to widespread adoption; provides practical insights from field deployments; promotes accessible and scalable technologies.	May compromise on data accuracy or robustness compared to higher-cost systems.
[15]	IoT real-time potable water quality monitoring and prediction model based on cloud computing	Leverages cloud for scalability and accessibility; enables continuous data flow and real-time insights; robust infrastructure.	Reliance on internet connectivity and cloud provider; potential data security concerns (though can be mitigated).
[16]	Water quality monitoring and control in urban areas via IoT and mobile applications	User-centric approach; intuitive interfaces for citizens and operators; enhances transparency and stakeholder participation.	Dependent on mobile app adoption and consistent use by end-users.
[17]	Real-time water quality prediction using Graph Neural Networks (GNNs) with sparse monitoring data	Effective with limited sensor coverage; leverages network topology to infer quality at unmonitored locations; comprehensive understanding.	Requires graph representation of the network; newer technology, may have scalability challenges for very large networks.
[18]	Comprehensive review of advances in machine learning and IoT for water quality monitoring	Offers broad synthesis of developments and trends; covers range of ML algorithms and IoT role.	(Review paper, specific method not applicable as primary focus).
[19]	Hybrid deep learning model for predicting water quality in municipal water management systems	Combines strengths of different DL architectures; achieves higher accuracy and robustness; captures diverse patterns.	Increased complexity in model design and implementation; potentially higher computational demands.

[20]	Overview of water management and industrial impact of IoT	Highlights IoT's role in efficient water usage, reduced waste, and environmental compliance across sectors.	(Broader overview, not specific to urban water supply predictive modeling).

IV. Recent Challenges

Data Heterogeneity and Quality: Urban water supply systems generate vast amounts of data from diverse sources, including various types of IoT sensors, SCADA systems, laboratory analyses, meteorological stations, and even social media. These data sources often differ in format, resolution, frequency, and reliability. Integrating such heterogeneous data seamlessly into a unified platform for AI model training and deployment is a significant challenge. Furthermore, the quality of sensor data can be compromised by calibration drifts, sensor failures, environmental noise, and communication errors. Missing values, outliers, and inconsistencies in the data can severely impact the accuracy and reliability of AI models, leading to erroneous predictions and potentially misleading operational decisions. Robust data cleaning, preprocessing, and imputation techniques are crucial but computationally intensive and require specialized expertise.

Model Interpretability and Explainability: While advanced AI models, particularly deep learning architectures, can achieve impressive predictive accuracy, their "black-box" nature remains a major challenge in critical applications like water quality monitoring. Water utility operators and decision-makers often require insights into why a particular prediction was made or what factors contributed to an anomaly. Without interpretability, gaining trust in AI systems and facilitating informed human intervention becomes difficult. For example, if an AI model predicts a contamination event, operators need to understand the underlying parameters and their correlations to effectively identify the source and implement corrective measures. Developing AI models that are not only accurate but also transparent and explainable, providing actionable insights into their decision-making process, is an ongoing research frontier.

Scalability and Computational Resources: Deploying AI-driven predictive modeling for real-time water quality monitoring across large-scale urban water supply networks presents significant challenges in terms of scalability and computational resources. A comprehensive system requires processing continuous streams of high-frequency data from thousands of sensors, running complex AI models in real-time, and generating immediate alerts and predictions. This necessitates robust cloud computing infrastructure, high-performance computing capabilities, and efficient data management systems. The computational cost associated with training and deploying sophisticated deep learning models on vast datasets can be substantial. Furthermore, ensuring low latency in predictions for real-time applications adds another layer of complexity, demanding optimized algorithms and efficient hardware utilization.

Cybersecurity and Data Privacy: As urban water supply systems become increasingly interconnected through IoT and AI, they also become more vulnerable to cyber threats. The real-time water quality data, if compromised, could be manipulated to trigger false alarms, disrupt operations, or even provide intelligence for malicious attacks on critical infrastructure. Ensuring the security of data transmission, storage, and processing is paramount to prevent unauthorized access, data breaches, and cyber-physical attacks. Moreover, with the increasing collection of data, including potentially sensitive information about water consumption patterns, data privacy concerns arise. Developing robust cybersecurity frameworks and adhering to strict data privacy regulations are essential to build trust and ensure the responsible deployment of AI-driven water management systems.

Integration with Existing Infrastructure and Legacy Systems: Many urban water utilities operate with existing infrastructure and legacy systems that may not be designed for seamless integration with modern IoT and AI technologies. These older systems often use proprietary protocols, have limited interoperability, and lack the necessary computational capabilities or data storage for real-time AI applications. Retrofitting or replacing entire infrastructure is often prohibitively expensive and time-consuming. Therefore, a significant challenge lies in developing adaptable AI solutions that can effectively integrate with and leverage existing infrastructure while gradually transitioning towards more advanced, interconnected systems. This requires flexible architectures, robust APIs, and careful planning to ensure a smooth and cost-effective modernization of urban water supply systems.

V. Conclusion & Future Scope

The integration of AI-driven predictive modeling into real-time water quality monitoring in urban water supply systems represents a transformative advancement, moving beyond reactive management to proactive intervention. This review has highlighted the significant progress made in leveraging diverse AI techniques, from traditional machine learning to advanced deep learning architectures and Graph Neural Networks, to analyze heterogeneous sensor data. These systems offer unprecedented capabilities for accurate water quality forecasting, early anomaly detection, and the optimization of treatment processes, thereby enhancing public health protection and operational efficiency. The shift towards intelligent water networks, enabled by the convergence of AI and IoT, promises a more resilient and sustainable urban water future.

Despite the remarkable progress, the field of AI-driven water quality monitoring still faces several critical challenges that define the future scope of research. Key areas for future work include developing more robust and generalizable AI models that can adapt to varying environmental conditions and infrastructure complexities, along with improving the interpretability and explainability of these models to foster greater trust and facilitate human-in-the-loop decision-making. Addressing data heterogeneity, quality issues, and ensuring the cybersecurity of interconnected systems will remain paramount. Furthermore, research into low-cost, energy-efficient sensor technologies and edge computing for distributed intelligence will be crucial for scalable and economically viable deployments. The integration of AI with digital twin technologies, advanced simulation models, and generative AI for system design and optimization holds immense potential for creating truly intelligent and adaptive urban water supply systems capable of anticipating and mitigating future risks.

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