

# Research on Water Resource Management and Sustainable Development in the Field of Water Supply and Drainage Engineering

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**Abstract:** Water resources, as the source of life, are crucial for the sustainable development of society. However, with the growth of the global population and the acceleration of industrialization, water resources are facing increasingly severe issues of scarcity and pollution. Water supply and drainage engineering plays a key role in water resource management and sustainable development. This paper explores the key technologies and methods in water resource management, with a focus on the latest developments in water resource monitoring and data collection technologies, water resource assessment and optimization methods, as well as water resource recycling and reuse technologies. Additionally, it discusses the core functions of water supply and drainage engineering in water resource supply, urban water supply and drainage system optimization, disaster response, and emergency management. Furthermore, the article analyzes the challenges and strategies for the sustainable development of water resources, presenting the current status and challenges of water resource scarcity and pollution, and exploring the balance between water resource protection and environmental impact. Finally, the paper provides a comprehensive analysis of the formulation of water resource sustainability policies and regulations, and the roles of society, economy, and technology. Through the discussion of relevant technologies and methods, this paper offers valuable insights for the optimization of future water resource management and the development of water supply and drainage engineering.

**Keywords:** Water Resource Management; Water Supply and Drainage Engineering; Sustainable Water Resource Development; Water Resource Recycling; Urban Water Supply and Drainage Systems

## Introduction

Water resources are the fundamental resources for human survival and development. With the growth of the global population, the acceleration of industrialization, and the impact of climate change, water resources face severe challenges, particularly in areas where water is scarce. The issues of shortage and pollution are becoming increasingly prominent, threatening sustainable social development. Water supply and drainage engineering plays a crucial role in water resource management, responsible for the supply, optimization of allocation, improvement of utilization efficiency, and public safety protection of water resources. This paper aims to study the key technologies and methods of water resource management and sustainable development, explore how water supply and drainage engineering can respond to water resource crises, analyze the application of water resource monitoring, assessment, and recycling technologies, and propose solutions, providing new ideas for water resource management and sustainable development.

## 1.Key Technologies and Methods in Water Resource Management

### 1.1 Water Resource Monitoring and Data Collection Technologies

Water resource monitoring and data collection are the foundation of water resource management, serving as the premise for scientific management and rational allocation. Effective monitoring technologies can track changes in water resource quantity and quality in real time, providing accurate data support for decision-makers. Common water resource monitoring methods include remote sensing technology, hydrometeorological monitoring, and automated water quality monitoring systems. Remote sensing technology obtains large-scale water body distribution and change information through satellite or drone images, playing a crucial role in large-scale regional water resource assessment.

Hydrometeorological monitoring involves installing equipment such as rain gauges, flow meters, and weather stations to collect real-time data on precipitation, river flow, and evaporation, providing immediate feedback for water resource management. Automated water quality monitoring systems use sensors to monitor the concentration of pollutants in water bodies, such as ammonia nitrogen, total phosphorus, and heavy metals, transmitting the data to monitoring centers for remote management. [1]

Additionally, with the integration of the Internet of Things (IoT), big data, and cloud computing technologies, the real-time performance and accuracy of water resource monitoring systems have been significantly enhanced. IoT technology connects various monitoring devices through sensor networks, collects data in real time, and analyzes and stores it through cloud platforms, thereby improving the intelligence of water resource management. In the future, as sensor technology progresses and data processing technologies develop, water resource monitoring will evolve toward greater precision and intelligence.

### ***1.2 Water Resource Assessment and Optimization Allocation Methods***

Water resource assessment and optimization allocation methods are important tools for achieving efficient utilization and sustainable development of water resources. The goal of water resource assessment is to determine the usable amount and distribution of water resources, providing a scientific basis for resource allocation. Assessment methods typically include evaluations of available water resources, water quality assessment, and spatiotemporal distribution analysis of water resources. The evaluation of available water resources combines factors such as precipitation, runoff, and groundwater, using hydrological models and water resource simulation software to make predictions, providing theoretical support for long-term regional water resource management.

In terms of water resource optimization allocation, common methods include linear programming, dynamic programming, and optimal scheduling models. Linear programming can be used to solve water supply-demand balance problems by establishing mathematical models to optimize water resource allocation. Dynamic programming is suitable for optimization that considers multi-period decisions and sequential issues, particularly excelling in cross-year water resource allocation. Optimal scheduling models are mainly applied to large-scale water conservancy projects such as reservoirs and dispatch systems, using simulation and optimization techniques to achieve dynamic water resource management. Furthermore, with the development of big data analytics and artificial intelligence technologies, data-driven optimization methods are gradually becoming a new trend in water resource management. These technologies can combine historical data and real-time data to make intelligent decisions, optimizing water resource allocation plans and improving water resource utilization efficiency.

### ***1.3 Water Resource Recycling and Reuse Technologies***

Water resource recycling and reuse technologies are one of the key means for achieving sustainable water resource development, especially in water-scarce regions. Water recycling and reuse not only effectively alleviate water resource shortages but also reduce environmental pollution, promoting the cyclic utilization of water resources. Common water recycling and reuse technologies include wastewater treatment, rainwater collection, and reclaimed water reuse. Wastewater treatment technologies, through physical, chemical, and biological treatment methods, remove harmful substances from wastewater to achieve standard discharge or reuse. Currently, membrane separation technologies (such as reverse osmosis membranes and nanofiltration membranes) and advanced oxidation technologies (such as ozone oxidation and ultraviolet light catalysis) are widely used in wastewater recycling, effectively removing pollutants from wastewater and ensuring that water quality meets reuse standards. [2]

Rainwater collection technology involves constructing rainwater harvesting systems to collect and store precipitation, providing supplementary water for urban or industrial use. As rainwater recycling technologies continue to improve, the treatment and storage equipment for rainwater is gradually becoming more intelligent and automated, improving collection efficiency and utilization rates. Reclaimed water reuse technology involves treating wastewater from industrial production, domestic sewage, and other sources, after which it can be used for non-drinking purposes such as toilet flushing and landscape irrigation, thus reducing water resource waste.

The development trend of water recycling and reuse technologies is toward greater efficiency, energy savings, and lower costs. For example, water treatment technologies combined with renewable energy sources like solar and wind power can further enhance the efficiency and cost-effectiveness of water recycling. With the application of intelligent technologies, water recycling and reuse are no longer limited

to single-stage physical-chemical treatment but are evolving toward multi-stage and multi-system integrated management, forming more flexible and efficient water recycling systems.

## **2. The Role of Plumbing Engineering in Water Resource Management**

### ***2.1 Core Functions of Plumbing Engineering in Water Resource Supply***

Plumbing engineering plays a crucial role in water resource supply, with its primary task being to ensure the stable supply of water resources to cities and regions, meeting the needs for domestic water use, industrial production, and agricultural irrigation. A plumbing engineering system is mainly composed of the water supply system and the drainage system. The water supply system transports water resources to users through processes such as source selection, treatment, storage, and distribution, while the drainage system is responsible for removing urban wastewater and rainwater, preventing urban flooding and water pollution.

In terms of water resource supply, plumbing engineering ensures the efficient use and rational allocation of water resources. For example, during urban water supply processes, by establishing intelligent water networks, plumbing engineering can monitor data such as water sources, pipeline flow, and water quality in real time, optimizing water supply plans and improving the utilization efficiency of water resources. Moreover, the pipeline systems within plumbing engineering can ensure water quality safety by reducing leakage and optimizing water quality treatment, meeting the diverse water needs of users. This is especially important in water-scarce areas, where the efficient use of limited water resources is critical. Plumbing engineering also enhances the supply capacity of water resources through rainwater collection systems and wastewater recycling, thereby improving the sustainability of water resource management. <sup>[3]</sup>

### ***2.2 Optimization and Enhancement of Urban Plumbing Systems***

With the acceleration of urbanization, urban plumbing systems face increasingly complex challenges. How to optimize and enhance urban plumbing systems, improve water resource utilization efficiency, and strengthen urban flood control and drainage capabilities has become a key issue in water resource management. The optimization of urban plumbing systems is first reflected in the intelligent management of the water supply system. Using modern information technologies such as the Internet of Things (IoT), big data analysis, and cloud computing, urban water supply can be monitored in real time at every stage, tracking the current supply status, predicting future demand, and adjusting supply plans accordingly. By optimizing the pipeline layout and material selection, water resource waste can be reduced, and water supply efficiency can be improved.

Optimizing the drainage system is equally important. With the growing urban population, the load on urban drainage systems has increased, especially during heavy rainfall, when traditional drainage systems may not be able to cope with large volumes of rainwater, leading to water accumulation and flooding. Optimizing drainage systems can be achieved through measures such as building rainwater storage ponds, increasing permeable pavements, and strategically planning urban green spaces to enhance the city's drainage capacity. The application of advanced rainwater utilization technologies and ecological water conservancy projects can effectively alleviate the pressure on urban drainage systems and enable rational use of rainwater. Additionally, upgrading urban sewage treatment systems is a focal point of optimization. Advanced treatment technologies, such as membrane separation and constructed wetlands, can improve sewage treatment rates, meet discharge standards, and promote the recycling of water resources.

### ***2.3 Disaster Response and Emergency Plumbing Systems Construction***

The construction of disaster response and emergency plumbing systems is an important measure to ensure water supply and drainage capacity in cities during natural disasters, particularly during extreme weather events such as floods, typhoons, and droughts. Traditional plumbing systems often face significant challenges during extreme weather events, especially when natural disasters like heavy rain and typhoons cause water resource accumulation and sewage discharge, requiring urgent support from emergency systems.

The core of building emergency plumbing systems lies in proactively planning emergency response plans and constructing emergency water sources, storage facilities, and drainage systems. By establishing emergency water source systems, such as diversified water source allocation mechanisms and mobile

water supply facilities, cities can still be provided with basic water supplies when regular water supply is interrupted. At the same time, emergency drainage systems must address low-lying areas and regions with poor drainage by setting up temporary pump stations and drainage pipelines to ensure that accumulated water is quickly removed after disasters, preventing urban flooding. [4]

In addition to hardware construction, the intelligence of emergency management is also a crucial means to improve the efficiency of emergency plumbing systems. Through big data analysis and real-time monitoring, the arrival of disasters can be precisely predicted, and the operation plans of emergency water sources and drainage systems can be dynamically adjusted. Intelligent systems can promptly respond to changes in disasters, optimize water resource scheduling and drainage arrangements, and improve the speed and effectiveness of emergency responses, thus reducing the impact of disasters on urban water supply and drainage capabilities.

### **3.Challenges and Countermeasures in the Sustainable Development of Water Resources**

#### ***3.1 Current Situation and Challenges of Water Scarcity and Pollution***

The issue of global water scarcity is becoming increasingly severe, especially in arid and semi-arid regions, where the supply of water resources cannot meet the rapidly growing demand. According to a report from the United Nations, approximately one-third of the global population faces water scarcity, a situation that may worsen in the coming decades. The causes of water scarcity include changes in natural conditions, the impact of climate change, and the accelerated growth of population and urbanization. As the demand for water from urban areas and agriculture increases, the over-exploitation and pollution of water sources have become more prominent, exacerbating the conflict between water supply and demand. Over-exploitation of water sources not only weakens the regeneration capacity of water bodies but may also lead to the decline of groundwater levels and ecosystem degradation, further affecting the sustainable use of water resources.

Water pollution is another major challenge contributing to water scarcity. With the acceleration of industrialization, the discharge of industrial and agricultural wastewater and domestic sewage has caused severe pollution of water bodies, particularly in water-scarce regions. Water pollution not only affects water quality but also reduces the availability of water resources and increases the difficulty of water resource management. Pollutants such as heavy metals, pesticide residues, and plastic micro-particles seriously harm the ecological environment and human health, and the process of removing these pollutants is often complex and costly. To address this challenge, it is necessary to strengthen the comprehensive protection and management of water resources, improve pollution control technologies, and implement stricter water pollution prevention and control measures to achieve the sustainable use of water resources. [5]

#### ***3.2 Balancing Water Resource Protection and Environmental Impacts***

In promoting the sustainable development of water resources, balancing water resource protection and environmental impacts is a key issue. Over-exploitation of water resources may lead to the destruction of aquatic ecosystems, such as river drying, wetland disappearance, and a reduction in biodiversity. Therefore, the development and use of water resources must follow the principle of environmental protection, minimizing negative impacts on the ecological environment. Over-extraction of groundwater and changes in natural water flow patterns may cause long-term damage to water ecosystems, even leading to the loss of ecological functions, affecting the living environment of local species and the ecological services they provide.

First, water-saving technologies and methods should be adopted to improve the efficiency of water use and reduce waste. For example, using advanced irrigation techniques (such as drip irrigation and sprinkler irrigation) and water-saving equipment, promoting rainwater harvesting systems, and strengthening water recycling can significantly reduce reliance on natural water sources. By improving water efficiency in agriculture, industry, and urban areas, it is possible to reduce pressure on water resources while ensuring demand is met. Second, strengthening the protection of water ecosystems is crucial to avoid over-exploiting water resources, implementing basin-wide management, and rationally allocating water resources. By establishing ecological protection red lines and strictly controlling the development and use of water resources, the sustainability of the water ecological environment can be ensured, and ecological damage can be minimized.

Furthermore, managing pollutant emissions is also an important aspect of water resource protection. Water quality monitoring and pollution control should be strengthened, and green production and low-carbon lifestyles should be promoted to reduce the generation of pollution sources. By implementing discharge standards and enhancing industrial wastewater treatment, water pollution can be effectively reduced, protecting water resources from contamination and promoting the healthy development of aquatic ecosystems. The sustainable use of water resources requires not only attention to development and utilization but also the strengthening of ecological protection, pollution control, and collaborative management to achieve both economic benefits and environmental protection.

### ***3.3 Formulating Water Resource Sustainable Development Policies and Regulations***

The sustainable development of water resources cannot be achieved without a sound policy framework and strict legal regulations. Governments and international organizations need to actively formulate and improve policies for water resource management, promoting the rational use and protection of water resources. First, governments should implement specific water resource management policies that clarify the goals for the development, utilization, and protection of water resources, and establish water resource assessment and monitoring mechanisms. At the same time, management measures should be tailored to the distribution and demand changes of water resources, implementing the optimal allocation of water resources.<sup>[6]</sup>

In terms of regulations, the legal system related to water resources should cover areas such as water pollution prevention, water rights management, and water use efficiency standards. Laws such as the Water Pollution Prevention Law, Environmental Protection Law, and Water Resource Protection Law should be further improved and strictly enforced to ensure that polluting enterprises comply with discharge regulations. Additionally, establishing a water rights system helps regulate the distribution of water resources and resolve issues related to water allocation and water rights disputes. In advancing the sustainable development of water resources, the effective implementation of policies and regulations is critical to ensuring the rational use of water resources and the protection of the ecological environment.

### ***3.4 The Role of Society, Economy, and Technology in the Sustainable Development of Water Resources***

The coordinated role of society, the economy, and technology is an essential guarantee for achieving the sustainable development of water resources. On the societal level, public awareness of environmental protection and water-saving behaviors directly impacts the effectiveness of water resource management. Governments, businesses, and the public must work together to promote water resource protection, spread water-saving knowledge, and enhance the appreciation of water resources. At the same time, the public should strengthen their understanding of water resource management policies and regulations, actively participate in water resource protection and environmental monitoring efforts.

On the economic level, economic incentive policies play an important role in promoting the sustainable development of water resources. Through economic measures such as water resource taxes, pollution fees, and green credit, businesses and individuals can be encouraged to pay more attention to water conservation and water pollution control. The promotion of a green economy model, particularly the development of green buildings, water-saving agriculture, and environmental protection industries, helps reduce water consumption, improve water use efficiency, and achieve a win-win situation for both the economy and the environment.

On the technological front, innovative technologies are a crucial support for promoting the sustainable development of water resources. Advanced water treatment technologies, such as membrane separation, reverse osmosis, and ultraviolet disinfection, can improve the purification of water, improve water quality, and increase the availability of usable water resources. Meanwhile, the application of smart water networks and IoT technology makes water resource management more efficient, enabling real-time monitoring and scheduling of water resources. The continuous advancement of wastewater treatment and water resource recycling technologies also provides effective solutions to the problem of water scarcity. Through technological innovation, water use efficiency can be significantly improved, reducing dependence on natural water sources and promoting the sustainable use of water resources.

## **Conclusion**

This paper systematically analyzes the key technologies and methods in water resource management

and sustainable development, exploring the multiple roles of plumbing engineering in water resource management. The study shows that sustainable management of water resources depends on efficient monitoring technologies, scientific evaluation and optimization methods, and innovative water resource recycling and reuse technologies. Although plumbing engineering plays a crucial role in ensuring water resource supply and responding to disasters, water scarcity, pollution, and environmental protection remain major challenges. In the future, water resource management will increasingly rely on informatization and intelligent technologies, particularly the applications of the Internet of Things and big data. Future research should focus on emerging technological innovations and promote multi-party cooperation among policies, society, the economy, and technology to foster the sustainable management and development of water resources.

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