Discussion on Key Technologies for Sewage Treatment in Municipal Water Supply and Drainage Design

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Abstract: With the rapid increase in urban population, municipal water supply and drainage systems are facing tremendous pressure. Sewage treatment plays a crucial role in urban water resource recycling and ensuring urban water environment quality. Traditional sewage treatment technologies struggle to meet increasingly stringent environmental standards. This paper analyzes the importance of sewage treatment in the field of municipal water supply and drainage design, proposes key sewage treatment technologies and optimization strategies—such as constructing separate stormwater and sewage treatment systems, conducting reasonable planning and design for sewage treatment, optimizing pipeline network design schemes, adopting intelligent monitoring measures, and improving sewage treatment infrastructure—to provide strong support for the efficient recycling and sustainable development of urban water resources.

1. Introduction

The municipal water supply and drainage system is a vital component of urban infrastructure. The sewage treatment technologies employed during its design phase directly impact the use and protection of urban water resources and determine the overall quality of the urban ecological environment. Sewage treatment technologies in municipal water supply and drainage design utilize rational and efficient technical methods to remove pollutants, enabling treated water to be recycled and alleviating pressure on scarce urban water resources. Therefore, urban water supply and drainage design should deeply explore the application paths of sewage treatment technologies to promote simultaneous improvement in treatment efficiency and quality.

2. Importance of Enhancing Sewage Treatment in Municipal Water Supply and Drainage Projects

2.1 Protecting Water Resources

Water resources are the lifeblood of urban development. Especially against the backdrop of accelerating urbanization, efficient sewage treatment in municipal water supply and drainage projects can better protect water resources. Scientific and effective sewage treatment technologies remove pollutants from water, allowing treated effluent to meet recycling standards and providing clean, safe water sources for the city [1]. Simultaneously, sewage treatment is a fundamental condition for maintaining ecological balance. Strengthening sewage treatment in municipal projects can mitigate the impact of wastewater on ecosystems, helping rivers, lakes, and other water bodies maintain a stable ecological environment. Furthermore, enhanced sewage treatment can alleviate urban water shortages. Deeply treated wastewater can be used in urban greening, road cleaning, and other areas, significantly improving water resource utilization efficiency. It is an indispensable guarantee for urban sustainable development and a powerful measure for protecting water resource security.

2.2 Improving the Ecological Environment

Municipal water supply and drainage projects, with advanced sewage treatment measures and well-developed pipeline networks, can collect and treat sewage centrally, remove harmful substances to meet recycling standards, reduce pollution of urban natural water bodies, and create favorable conditions for subsequent water resource recycling. Additionally, sewage treatment technologies can properly handle greenhouse gases produced by the decomposition of organic matter in wastewater, cutting off channels for these gases to pollute the air environment, thereby better protecting soil and air quality. Moreover, strengthening sewage treatment allows cities to attract investment and tourists with clean water bodies and a good ecological environment, enhancing the city's overall image and ecological quality, and improving the urban ecological environment in multiple aspects.

2.3 Promoting Urban Green Development

Sewage treatment technology in municipal water supply and drainage projects is a necessary link in promoting urban green development. Through centralized collection and deep treatment of sewage, municipal projects can reduce harmful substances in wastewater, ensuring the treated water quality meets discharge standards. The improvement in sewage treatment levels also symbolizes the green transformation of the urban economy. A good water resource environment will attract more investment and is the foundation for vigorously developing the tourism industry. Cities can also enhance their attractiveness with clean water bodies and a beautiful ecological environment, thereby driving the high-quality development of related green industries and providing a fundamental guarantee for the green and sustainable development of the urban economy.

3. Key Sewage Treatment Technologies in Municipal Water Supply and Drainage Design

3.1 Variable Frequency Water Pump Control Technology

Variable frequency water pump control technology plays a key role in sewage treatment for municipal water supply and drainage projects, significantly improving treatment efficiency and energy savings. This technology can monitor sewage flow in real-time. High-precision flow sensors installed in sewage pipelines continuously collect flow data and transmit it to the control center. The control center calculates the pump's operating frequency precisely based on preset flow parameters[2]. Variable frequency pump control technology also features soft start functionality. It can smoothly adjust voltage and frequency during start and stop periods, avoiding the large current impact generated during the startup of traditional pumps, thereby reducing the impact on the power grid. The core principle of this technology is based on AC variable frequency speed regulation. The frequency converter installed on the pump motor changes the power supply frequency in real-time, thus steplessly regulating the motor's speed. This advantage effectively enhances process control accuracy and stability, ensuring the liquid level in the collection well or the sludge return flow in the biochemical tank remains within the optimal range. Subsequent treatment units can operate in a stable and efficient state, ultimately optimizing the effluent quality.

3.2 Vortex Grit Chamber Technology

This technology is a core pretreatment unit in municipal water supply and drainage sewage treatment, offering high grit removal efficiency and low energy consumption. During application, the vortex grit chamber technology uses mechanical drive or water flow rotation to form a centrifugal force field, separating grit and organic matter from the sewage. Wastewater typically enters the tank tangentially and is then converted into a spiral flow pattern under the action of a

turbine. Organic matter is discharged with the central upward flow. Vortex grit chambers also possess good impact load resistance, maintaining stable grit removal efficiency even with flow fluctuations of up to 30%. It is a core technical means for achieving refined operation in municipal sewage treatment.

3.3 Oxidation Treatment Technology

Oxidation treatment technology is a core technical method in municipal water supply and drainage sewage treatment. Its main principle is to use strong oxidation to degrade organic matter, achieving decolorization and deodorization. Among these, electrocatalytic oxidation technology performs excellently in treating phenol-containing wastewater. Wet catalytic oxidation technology can convert organic matter in sewage into carbon dioxide and water, thus providing a more flexible technical choice for municipal water supply and drainage sewage treatment with its advantages of high efficiency and low energy consumption.

4. Optimization Strategies for Sewage Treatment in Municipal Water Supply and Drainage Design

4.1 Constructing Separate Stormwater and Sewage Treatment Systems

Sewage treatment in municipal water supply and drainage projects should involve constructing separate stormwater and sewage treatment systems. GIS geographic information systems and pipeline network detection technologies should be used to create 3D models of existing combined sewer networks, accurately identifying points of stormwater and sewage mixing and illegal sewage discharge outlets. Relevant departments should also 划分 (delineate) drainage units based on urban topography and drainage characteristics, prioritizing the renovation of areas with frequent mixing, such as old urban districts and urban villages. On this basis, municipal water supply and drainage projects should establish smart drainage platforms integrating IoT monitoring equipment and digital twin technology. Deploy flow meters and water quality sensors at key nodes to collect indicators like COD and SS in real-time, and use machine learning algorithms to predict the operational status of the pipeline network. Technologies such as pipeline robots and water quality/quantity monitoring equipment can be used to conduct in-depth investigations of the actual condition of the drainage network, accurately identify points of stormwater and sewage mixing or misconnection, and assess pipeline health and drainage capacity. Priority should be given to converting areas with severe mixing and sensitive water bodies to separate systems. Technically, separate stormwater drainage systems should be established to collect rainwater runoff from building roofs, squares, and roads directly and discharge it into natural water bodies or rainwater utilization facilities nearby. Integrating the sponge city concept, promote source facilities like permeable pavements and sunken green spaces to effectively reduce total runoff volume and pollution load. Furthermore, successful separate system conversion relies on sound policies and regulations and broad public support. Governments should issue corresponding regulations clarifying the responsibilities and obligations of property owners, developers, and residents in stormwater and sewage separation, restrain illegal discharge behaviors, explain the importance of separation for improving the living environment, and encourage community residents to actively participate in supervision and maintenance. This helps avoid misconnections like washing machine discharge into storm drains at the source, achieving the comprehensive goal of enhancing rainwater resource utilization [3].

4.2 Conducting Proper Planning and Design for Sewage Treatment

Proper planning and design for sewage treatment in municipal water supply and drainage projects

are key to enhancing treatment efficiency and ensuring urban water environment quality. In the initial planning stage, conduct comprehensive research on urban population size, distribution, and water usage habits, grasp the effluent discharge situation of industrial enterprises, and understand the operational status of existing sewage treatment facilities. Through in-depth analysis of this data, clarify the characteristics and variation patterns of sewage water quality and quantity, providing a solid basis for subsequent planning. Sewage treatment must also predict future sewage generation based on survey data to determine the construction scale of sewage treatment plants. Avoid both oversized scales causing resource waste and undersized scales failing to meet treatment demands. For sewage with complex water quality and high treatment requirements, processes combining biological treatment and advanced treatment can be selected. Meanwhile, sewage treatment should focus on planning flexibility and expandability, reserving certain space for future facility expansion and process upgrades based on actual needs. The entire planning process requires relevant municipal departments to comprehensively consider urban development factors, use various models for medium-to-long-term predictions, and avoid designs that are either too ahead of their time or lagging. Additionally, process selection is the core of planning and design. Relevant departments should compare and select technologically mature processes with low energy and material consumption. Actively introduce new low-carbon and energy-saving technologies centered on anaerobic ammonium oxidation (anammox), aerobic granular sludge, etc. The site selection and design of sewage treatment facilities should fully consider harmonious coexistence with the surrounding environment, creating a truly efficient, low-carbon, and future-oriented sewage treatment system for the city.

4.3 Optimizing Pipeline Network Design Schemes

The scientific nature of pipeline network design schemes in municipal water supply and drainage sewage treatment systems directly affects sewage collection efficiency and treatment costs. The pipeline network layout should refer to urban spatial planning and sewage discharge characteristics, adopting a zoned and graded design concept to divide the service area into several independent drainage zones. Each zone should have an independent outlet matched with a corresponding treatment scale. Use GIS platforms to establish 3D pipeline network models, simulate sewage flow changes under different rainfall intensities, dynamically adjust pipeline route and burial depth, and avoid conflicts with underground utilities and building foundations. During this process, relevant departments can use CFD technology to optimize the pipeline profile design, controlling the maximum flow velocity while ensuring the minimum flow velocity has self-cleaning capability. For long-distance transmission pipes, promote the use of new pipe materials such as ductile iron pipes and HDPE steel strip reinforced pipes to keep pump operating efficiency near the optimal working point. Meanwhile, the key to optimizing pipeline network design in municipal projects lies in top-level planning. Use modern hydraulic modeling software for precise simulation calculations, optimize pipe diameter, slope, and burial depth to ensure the pipeline network operates efficiently and stably during both dry weather full flow and wet weather flood season. Furthermore, pipeline network design should combine gray infrastructure (pipes) with green facilities to reduce runoff volume and pollution load at the source, alleviate the pressure on pipeline transport and discharge, replenish groundwater, and achieve simultaneous improvement in environmental and economic benefits. The design phase should abandon the traditional model solely focused on construction cost, introduce life-cycle cost analysis, comprehensively analyze the total cost of design, construction, operation, and maintenance phases, and build an efficient and reliable modern drainage pipeline network system, providing a solid foundation for urban sustainable development.

4.4 Adopting Intelligent Monitoring Measures

Municipal water supply and drainage sewage treatment should establish intelligent monitoring measures by deploying various types of sensors at key nodes. Use water quality sensors to monitor key indicators like COD and BOD in real-time, accurately grasping changes in water quality. Install flow sensors and pressure sensors to monitor sewage flow, liquid level height, and pipeline pressure in real-time, forming a monitoring network covering the entire sewage treatment process and providing abundant data references for intelligent control. Relevant departments should also establish an intelligent monitoring platform integrating data collection, transmission, and analysis. deeply mine and analyze the massive monitoring data to promptly identify potential issues such as abnormal water quality fluctuations and equipment operational failures [4]. On this basis, constructing a digital twin model for sewage treatment is also very important. It can simulate and test the effects of different operation schemes in virtual space, providing scientific decision support for process modification, capacity expansion, and standards upgrade, and minimizing trial-and-error costs. Furthermore, the ultimate goal of intelligent monitoring in municipal sewage treatment is to form closed-loop management. Therefore, in the actual supervision process, develop supporting mobile operation and maintenance APPs to push key data, early warning information, and equipment status to managers' mobile terminals, facilitating control over project operation status anytime and anywhere, and significantly improving management efficiency.

4.5 Continuously Improving Sewage Treatment Infrastructure

Sewage treatment in municipal water supply and drainage projects should continuously improve its infrastructure, conducting scientific and reasonable forward-looking planning based on urban development plans and population growth trends. In new development areas, plan supporting sewage treatment facilities in advance. In old urban areas, assess the gap between the capacity of existing facilities and future demand, and formulate phased renovation and upgrade plans. Municipal projects should actively introduce advanced sewage treatment technologies and processes, carry out technological transformations of existing treatment facilities, promptly phase out aging equipment, and adopt intelligent control systems for remote equipment supervision, reducing labor costs and operational risks. The construction of sewage treatment infrastructure also requires actively broadening financing channels. Beyond basic government financial investment, encourage social capital to participate in the construction and operation of sewage treatment infrastructure, providing financial guarantee for the continuous improvement of facilities. Additionally, the continuous improvement of infrastructure must be closely integrated with the new requirements of the "Dual Carbon" goals Peak Carbon Dioxide Emissions and Carbon Neutrality, ensuring systematic planning and precise investment. Regarding infrastructure renovation, maintain a long-term development perspective, incorporate needs such as climate change response and new pollutant standards into planning, ensuring infrastructure can deliver maximum value and achieve good environmental benefits.

5. Conclusion

In summary, strengthening sewage treatment in municipal water supply and drainage projects can effectively enhance urban wastewater treatment levels and improve the quality of life for the people. Therefore, relevant managers must prioritize the optimization of sewage treatment, construct separate stormwater and sewage treatment systems, conduct proper planning and design for sewage treatment, optimize existing pipeline network design schemes, adopt intelligent monitoring measures, and continuously upgrade and improve sewage treatment infrastructure to fully realize

the maximum application value of sewage treatment technologies.

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