

Review

Current Status of and Suggestions on Sewage Treatment Fees in China

Guoming Zeng ^{1,2,3,4}, Zilong Ma ^{1,2}, Yu He ², Lin Chen ⁵, Da Sun ^{6,7,8,*}  and Xiaoling Lei ^{2,*}

¹ School of Architecture and Engineering, Chongqing University of Science and Technology, Chongqing 401331, China

² Chongqing Academy of Science and Technology, Chongqing 401123, China

³ School of Civil Engineering, Chongqing Jiaotong University, Chongqing 400074, China

⁴ Intelligent Construction Technology Application Service Center, Chongqing City Vocational College, Chongqing 402160, China

⁵ Chongqing Shapingba District Ecological Environment Bureau, Chongqing 401331, China

⁶ National & Local Joint Engineering Research Center for Ecological Treatment Technology of Urban Water Pollution, College of Life and Environmental Science, Wenzhou University, Wenzhou 325035, China

⁷ Zhejiang Provincial Key Laboratory for Water Environment and Marine Biological Resources Protection, College of Life and Environmental Science, Wenzhou University, Wenzhou 325035, China

⁸ Institute of Life Sciences, Biomedical Collaborative Innovation Center of Zhejiang Province, Wenzhou University, Wenzhou 325035, China

* Correspondence: sunday@wzu.edu.cn (D.S.); ellenlei2008@126.com (X.L.)

Abstract: China's sewage treatment standards have been gradually improving, yet there is a widening gap between sewage treatment fees and actual costs. This discrepancy, where the fees for sewage treatment are lower than the actual operational expenses, poses a significant bottleneck to the sustainable development of China's sewage treatment industry. As a core aspect of environmental economic policies, sewage treatment fees are pivotal in regulating water pollution emissions and addressing water resource shortages. Currently, there are major issues with sewage treatment fees, including an incomplete pricing system, insufficient fees, unclear fee distribution, and a heavy reliance on local finances. These problems impede systematic planning, diminish management efficiency, and hinder the sustainable development of the sewage treatment industry. Thus, future research efforts should prioritize the establishment of a pricing mechanism that comprehensively covers the full cost of sewage treatment. This article presents a concise summary and review of the current situation, types of fee collection, cost accounting methodologies, challenges, and proposed countermeasures for sewage treatment fees, and could serve as a relevant reference for future research on sewage treatment fees. By comprehensively addressing these issues, the sewage treatment industry would progress towards healthier and more sustainable development, ultimately achieving the goal of green growth.

Keywords: sewage treatment fee; full cost price mechanism; polluter pays principle



Citation: Zeng, G.; Ma, Z.; He, Y.; Chen, L.; Sun, D.; Lei, X. Current Status of and Suggestions on Sewage Treatment Fees in China. *Water* **2024**, *16*, 1219. <https://doi.org/10.3390/w16091219>

Academic Editor: Andreas Angelakis

Received: 2 March 2024

Revised: 17 April 2024

Accepted: 22 April 2024

Published: 25 April 2024



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1. Introduction

Sewage treatment fees, as an environmental and economic policy, are a key measure to control water pollution emissions and address water resource shortages [1–5]. With China's ongoing advancement in ecological civilization construction, sewage treatment standards are progressively rising. However, there is a widening gap between sewage treatment fees and actual operational costs. Financial constraints in many areas struggle to sustain or cover these expenses, posing a significant challenge to China's sewage treatment industry's sustainable development [6]. Thus, the urgency of addressing this issue cannot be overlooked, and it is imperative to rapidly establish reasonable sewage treatment fee standards and implement a dynamic adjustment mechanism to ensure the comprehensive coverage of sewage treatment costs and enhance the sustainable development of the industry [7,8].

Simultaneously, as China's economy and society continue to develop, the issue of water resource constraints will become increasingly prominent, amplifying the pressure for water pollution prevention and control. Sewage treatment, an essential aspect of water pollution prevention and control, plays a significant role in promoting the ecological priority and green development of the Yangtze River Economic Belt [9–11]. Therefore, effectively using price mechanisms to promote water conservation and emission reduction is not only an immediate necessity but also essential for achieving long-term sustainable development. The data presented in Figure 1a,b [12] depict the sewage discharge and treatment volumes in Chinese cities from 1980 to 2020.

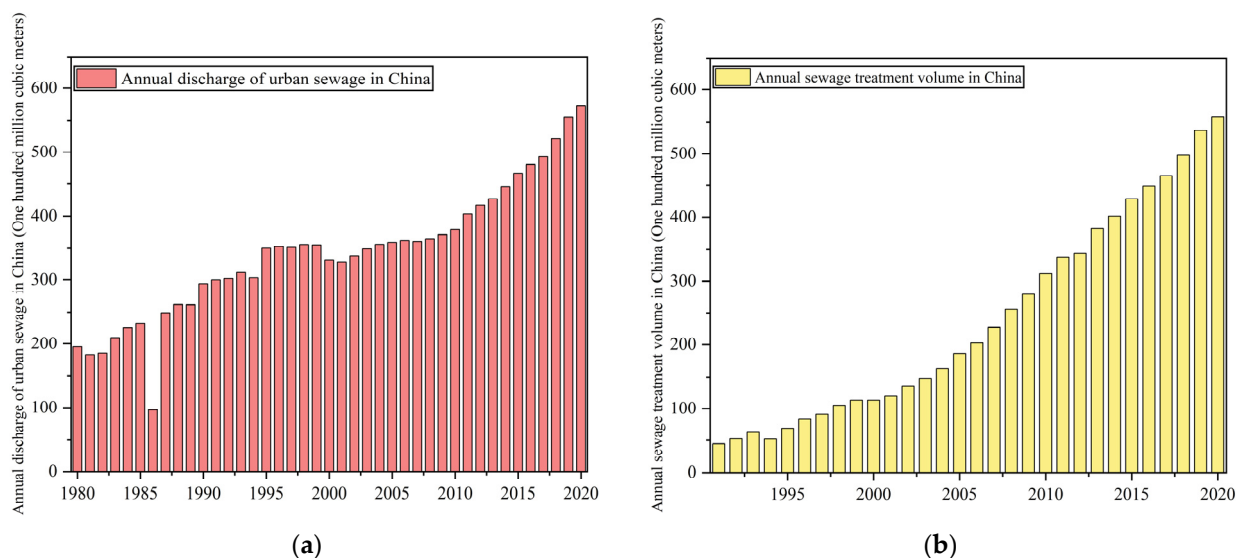


Figure 1. The data presented in (a,b) depict the sewage discharge and treatment volumes in Chinese cities from 1980 to 2020. (a) Annual discharge of urban sewage in China; (b) Annual sewage treatment volume in China.

The current sewage treatment fee system faces several significant challenges. Firstly, its pricing system is flawed, resulting in fragmented management within the sewage industry and contributing to issues like delayed dredging maintenance and ineffective cost allocation, which severely impact sewage treatment effectiveness and the sustainable development of urban water environments. Secondly, fee allocation lacks transparency and overly depends on local finances, leading to poor relations among stakeholders, limited urban interaction, and structural deficiencies in sewage networks, thereby reducing sewage treatment system efficiency. Moreover, the density of China's urban drainage networks is significantly lower compared with developed countries due to a consistent lack of funding support, impeding sewage treatment system enhancements. Lastly, inadequate sewage treatment fees exacerbate water resource wastage and insufficient infrastructure investment, resulting in deteriorating treatment quality, increased water pollution, and threats to both the environment and human health. Citizens' reluctance to pay equitable prices for public services like water and sewage treatment, coupled with management's hesitance to adjust service fees, has led to inadequate investment and financial deficits. These issues undermine systematic planning, impair management efficiency, and hinder the sustainable development of the sewage treatment industry. Figure 2 [12] illustrates the length of urban drainage pipes in Chinese cities from 1980 to 2020.

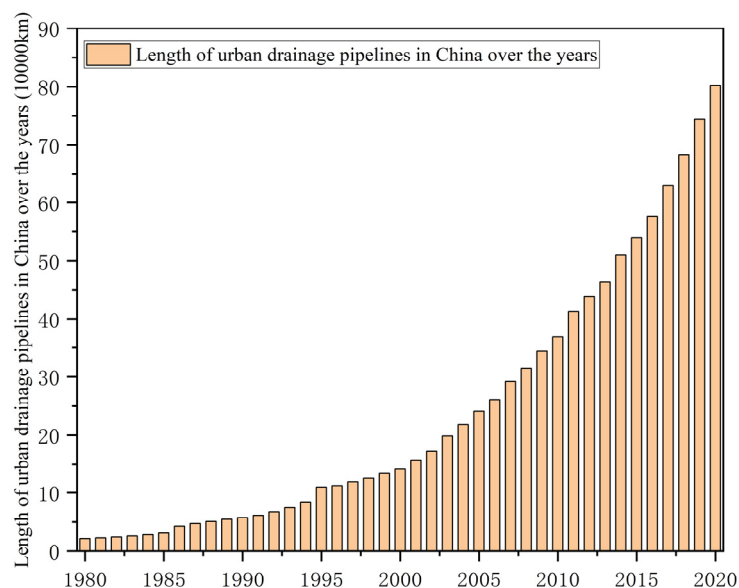


Figure 2. Length of urban drainage pipelines in China over the years.

This article provides a comprehensive overview and analysis of five key aspects related to sewage treatment fees: the current status, types of fee collection, cost accounting, major challenges, and proposed solutions. Initially, it examines and evaluates the present state of sewage treatment fees, elucidating their fundamental principles, diversity, and practical applications across different regions. Then, it discusses the various methods of fee collection, utilizing representative provinces and cities to illustrate the implementation of different collection approaches. Moreover, the article describes the disparities in sewage treatment cost accounting, particularly focusing on operating costs and highlighting practices within the Yangtze River Economic Belt. Following this, it thoroughly assesses the primary issues confronting sewage treatment fees, including flawed pricing systems, unclear fee allocation, and inadequate fee levels. Finally, this article presents a series of targeted recommendations to address these challenges, aiming to offer valuable insights for future research on sewage treatment fee management.

2. The Current Status of Sewage Treatment Fees

In 2007, Jinan City formulated the “Jinan City Urban Sewage Treatment Fee Collection and Utilization Management Measures” in compliance with directives from the Shandong Provincial Government, which outlined the principles of dual-line budgeting. Then, in October 2013, the State Council issued the “Regulations on Urban Drainage and Sewage Treatment”, followed by the promulgation of the “Measures for the Collection and Utilization of Sewage Treatment Fees” by the Ministry of Finance in December 2014. In January 2015, the National Development and Reform Commission, the Ministry of Finance, and the Ministry of Housing and Urban-Rural Development jointly issued the “Notice on Formulating and Adjusting Issues Related to Sewage Treatment Fee Standards”. This series of policies established the fundamental framework for the implementation of dual-line budgeting in urban sewage treatment fee management across China [13,14]. The current status of sewage treatment fees in major cities in China is shown in Figure 3 [15].

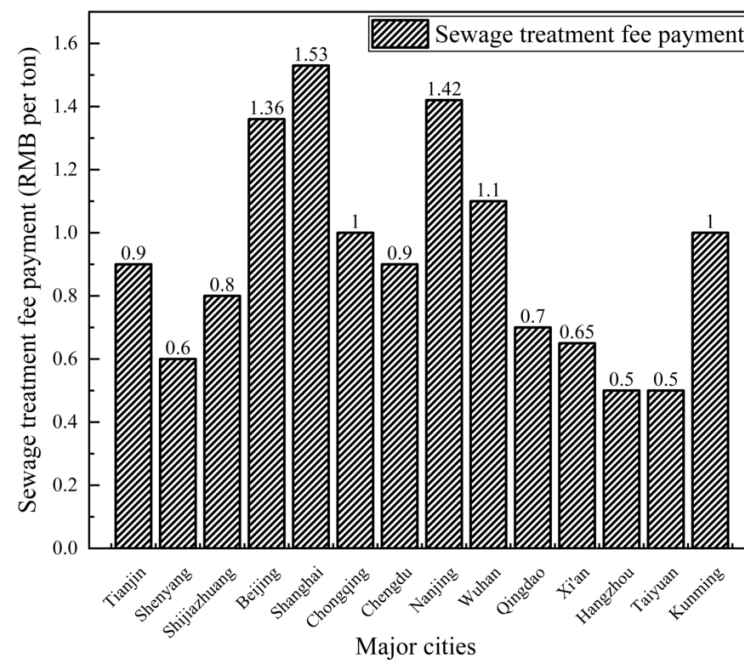


Figure 3. Current Status of Sewage Treatment Fees in Major Cities.

The framework system for analyzing sewage treatment fees based on the operating costs of sewage treatment plants is shown in Figure 4 [16].

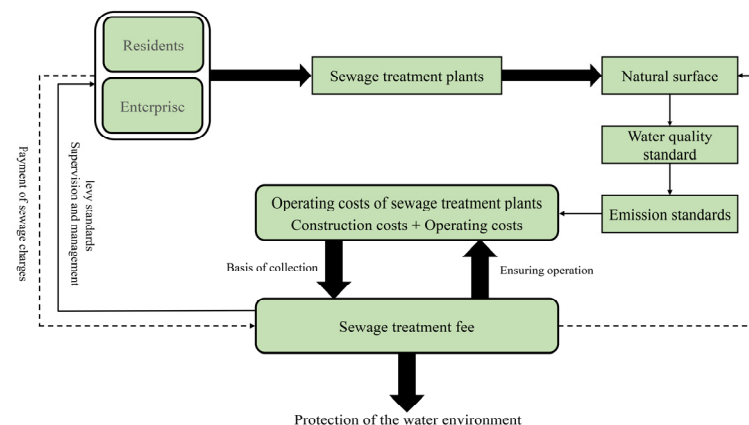


Figure 4. Analytical framework of sewage treatment charge based on operating cost of sewage treatment plant.

In 2018, the National Development and Reform Commission issued the “Opinions on Innovating and Improving the Price Mechanism to Promote Green Development”, which supports the fundamental principle of “polluter pays” and offers relevant recommendations for improving sewage treatment fee policies. In the 1970s, the Organization for Economic Co-operation and Development (OECD) proposed the “polluter pays” principle, which was officially recommended by the OECD in 1972 as a “guiding principle on the international economic aspects of environmental policies” [17]. The “polluter pays” principle [18–25] is an institutional framework designed to internalize the costs associated with mitigating negative environmental impacts. According to this principle, individuals or entities responsible for pollution at its source should bear these costs. The primary aim is to counteract the trend of externalizing costs. Environmental pollution typically involves externalities, leading polluters to avoid responsibility. By imposing pollution fees on these sources, the environmental costs of pollution are incorporated into the private costs of polluters, a process known as internalizing external costs. This increase in internal costs influences the

behavior and decisions of polluters, encouraging emission reduction, efficiency improvements, and ultimately facilitating the effective allocation of environmental resources by the entire economic system [26,27].

In China, the sewage treatment fee is based on the “polluter pays” principle, involving contributions from both drainage units and individuals. The funds collected are specifically designated to support the construction, operation, and management of urban sewage treatment facilities, including the treatment and disposal of sludge. If the collected sewage treatment fee cannot ensure the normal operation of urban drainage and sewage treatment facilities, local finances are responsible for providing subsidies. The collection standards for sewage treatment fees are established with the aim of covering the normal operation and ensuring reasonable profit for sewage treatment facilities, as well as covering the costs of sludge treatment and disposal. If the current collection standards for sewage treatment fees do not temporarily meet the criteria for covering the normal operation and reasonable profit of sewage treatment facilities, as well as the sludge treatment and disposal costs, adjustments should be made gradually. Since 2013, various national departments have issued multiple policies, which have played a constructive role in promoting and enhancing the sewage treatment fee mechanism. These departmental policies are outlined in Table 1.

Table 1. Departmental Policies.

Time	Publishing Unit	Policy
January 2015	National Development and Reform Commission, Ministry of Finance of the People’s Republic of China, Ministry of Housing and Urban-Rural Development of the People’s Republic of China	“Notice on the Formulation and Adjustment of Sewage Treatment Fee Standards and Related Issues”
April 2015	State Council	“Notice on the Issuance of the Action Plan for Water Pollution Prevention and Control”
July 2018	National Development and Reform Commission	“Opinions on Innovating and Improving the Price Mechanism to Promote Green Development”
April 2019	Ministry of Finance of the People’s Republic of China	“Announcement on the Corporate Income Tax Policy Issues for Third-Party Enterprises Engaged in Pollution Prevention and Control”
April 2020	National Development and Reform Commission, Ministry of Finance of the People’s Republic of China, Ministry of Housing and Urban-Rural Development of the People’s Republic of China, Ministry of Ecology and Environment of the People’s Republic of China, Ministry of Water Resources of the People’s Republic of China	“Guiding Opinions on Policies for Improving the Sewage Treatment Fee Mechanism in the Yangtze River Economic Belt”

3. Types of Sewage Treatment Fee Collection

In China, the pricing mechanism of sewage collection and treatment systems primarily refers to the collection and utilization of sewage treatment fees, which can be categorized into the following three contexts.

3.1. Specialized Use of Sewage Treatment Fees for Sewage Treatment Systems

In some provinces, strict adherence to the provision that “sewage treatment fees are specifically designated for the construction, operation, and sludge treatment and disposal of sewage treatment facilities, as well as the handling fees for sewage treatment fees, and may not be diverted for other purposes” [28] results in sewage treatment fees not being utilized for the construction and operation of sewage pipe networks, including provinces and cities such as Tianjin and Zhejiang.

3.2. Coordinated Use of Sewage Treatment Fees for Sewage Collection and Treatment Systems

The coordinated utilization of sewage treatment fees for both sewage treatment systems and sewage collection systems is exemplified by provinces and cities including Sichuan, Jiangsu, Hubei, Hunan, Anhui, Shaanxi, Beijing, and Guangdong.

3.3. Separate Collection of Drainage Pipe Network Maintenance Fees for Sewage Collection Systems

Some provinces and cities have implemented policies to collect drainage pipe network maintenance fees from users, with these fees designated specifically for the construction and operation of sewage collection systems. For instance, starting in 2010, Urumqi began collecting drainage pipe network maintenance fees alongside sewage treatment fees within the comprehensive unit price of tap water. In 2017, Urumqi adjusted the collection standard for drainage pipe network maintenance fees from CNY 0.1 per ton to CNY 0.25 per ton [29].

4. Cost Accounting of Sewage Treatment Facilities

In the context of sewage treatment costs in China, electricity is the primary operational expense, followed by labor or equipment depreciation costs and, finally, the consumption of chemical substances. However, in practice, there are limited data on effective statistics regarding chemical raw material consumption and equipment depreciation, particularly the latter. This limitation arises due to the significant differences resulting from variations in construction cycles, economic development conditions, treatment processes, and other factors [7].

4.1. Cost Accounting of Sewage Treatment in the Yangtze River Economic Belt

To address the urgent need of adjusting sewage treatment fees, Liu et al. [30] focused on clarifying the cost accounting of sewage treatment within the Yangtze River Economic Belt by analyzing the total investment and construction scale of nearly 2000 sewage treatment plants already operational in the region. They estimated the comprehensive average unit depreciation cost for the treated water quantity in these completed sewage treatment plants to expedite the improvement of the sewage treatment fee mechanism, specifically within the Yangtze River Economic Belt, aiming to set a model and provide guidance for the nationwide reform of sewage treatment fee mechanisms. The accounting conditions and reference materials for various costs are outlined below:

4.1.1. Electricity Cost

In accordance with the requirements of “Opinions on Innovating and Improving the Pricing Mechanism to Promote Green Development”, a unified electricity pricing method has been implemented for calculation purposes. The electricity price is determined based on the guiding electricity prices published by the National Development and Reform Commission as of July 2019 for each province and city. Data on the average electricity consumption per ton of water were obtained from a statistical analysis of the “Urban Drainage Yearbook” (2018 edition).

4.1.2. Staff Wages and Salaries

Labor quotas are determined based on the current relevant standards for sewage treatment project construction and statistical data from actual operations. The calculation of average labor costs considers the average salaries of urban unit employees in the water resources, environmental, and public facility management sectors, as published by statistical bureaus in various provinces and cities. Additionally, it takes into account the corresponding proportion of “five insurances and one fund” in the total remuneration.

4.1.3. Medicament Expenses

This category primarily encompasses expenses for four types of agents: disinfectants, coagulants, carbon sources, and phosphorus removal agents. The unit prices for each

type of agent are determined based on the average market price. Concerning dosage, the usage of disinfectants and coagulants relies on empirical averages, while the dosage of carbon sources and phosphorus removal agents is determined by various factors such as the average influent nitrogen and phosphorus concentrations, effluent nitrogen and phosphorus control concentrations, and the achievable removal ratios of nitrogen and phosphorus through conventional biochemical treatment. Data on the average influent nitrogen and phosphorus concentrations for each province and city are derived from statistical analysis of the “Urban Drainage Yearbook” (2018 edition).

4.1.4. Repairs and Other Expenses

Repair costs are estimated by considering the original value of fixed assets and applying an empirical repair cost rate. Other expenses are estimated as a certain percentage of the sum of the aforementioned expenses. The calculated values for the operational costs of sewage treatment in the Yangtze River Economic Belt are presented in Table 2 [30].

Table 2. Accounting Values for Operational Costs of Sewage Treatment in the Yangtze River Economic Belt by Region.

Region	Operating Cost of Sewage Treatment CNY/m ³
Upper Reaches Region	0.41~0.77
Middle Reaches Region	0.38~0.60
Lower Reaches Region	0.44~1.01

4.1.5. Depreciation Expense of Fixed Assets

The calculation of fixed asset depreciation involves several factors, including the construction investment of sewage treatment plants and the designated depreciation period, necessitating a specific analysis for each project. The comprehensive average water depreciation fee for sewage treatment facilities in the Yangtze River Economic Belt is illustrated in Figure 5 [30].

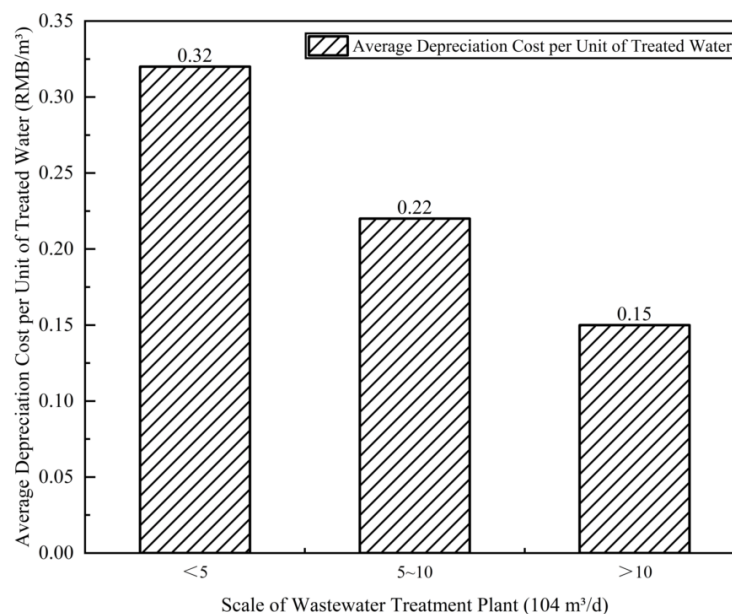


Figure 5. Comprehensive Average Depreciation Cost of Water for Sewage Treatment Facilities in the Yangtze River Economic Belt.

5. Main Issues of Sewage Treatment Fees

The lack of a comprehensive, full-cost, and full-life pricing mechanism has resulted in a range of issues within the sewage treatment sector. As demands for water conservation and the protection of aquatic ecological environments continue to escalate, these problems are becoming increasingly prominent, directly impeding the healthy development of the sewage treatment industry.

5.1. Incomplete Pricing System

In China, there is a significant difference between fees and prices in sewage collection and treatment, lacking a unified approach. This difference directly results in management challenges within the sewage industry, leading to numerous avoidable issues. Factors such as delayed dredging maintenance, evasion of responsibility, and ambiguous roles contribute to scenarios where sewage treatment plants experience low inflow and pollutant concentration despite substantial input costs. Moreover, the influx of industrial sewage exceeding standards disrupts the stable operation of urban sewage treatment plants and impedes the utilization of sewage regeneration and sludge treatment products. Additional complexities arise from issues like incorrect pipeline connections, improper slopes, and unauthorized discharges. As a result, the industry confronts significant obstacles stemming from the separation of fees and prices and fragmented management [31]. Urgent improvements are imperative to address challenges such as delayed dredging maintenance and unclear responsibilities, as neglecting these issues will adversely affect sewage treatment effectiveness and the sustainable development of urban water environments.

5.1.1. A Sample of 227 Sewage Treatment Plants Nationwide

In existing analyses of sewage treatment fee systems, little attention is paid to construction costs when estimating the total costs of sewage treatment plants, and there is limited correlation analysis between the operating costs of sewage treatment plants and sewage treatment fees [32–35]. Tan et al. [16] conducted research on a sample comprising 227 sewage treatment plants nationwide. By estimating the operating costs and their structures of these samples and conducting an in-depth analysis of the relationship between regional differences and implementation standards, the results revealed that the average operating cost of the samples is 1.38 CNY/ton. Upon comparing these data with the collection standards of sewage treatment fees in various regions, it was observed that in most areas of China, the current collected sewage treatment fees only cover the operating costs of sewage treatment plants rather than the entire operating costs of urban sewage treatment plants. In the cost-benefit analysis of studying the operation status of sewage treatment plants, it was found that the average unit revenue of sewage treatment fees for the 227 samples is 0.80 CNY/ton, the average unit benefit of treating sewage is 3.24 CNY/ton, and the average unit profit level is 2.09 CNY/ton. Fiscal subsidies constitute the largest proportion of income sources in sewage treatment plants, while the proportion of sewage treatment fees is relatively small. Moreover, some subsidies in both residential and industrial enterprises contradict the “polluter pays” principle.

The pricing of sewage treatment fees should be adjusted based on the local conditions to ensure fairness. While adjusted collection standards can cover a larger proportion of the operating costs of sewage treatment plants, there are still regions where costs exceed the pricing of sewage treatment fees. Therefore, formulating sewage treatment fees should consider the specific differences in social and economic development across regions. The differentiated pricing of sewage treatment fees should be implemented for different emitters. The environmental capacity in western regions may differ from that in eastern and central regions, which could lead to variations in the operational costs of sewage treatment plants. If costs remain high in western regions, consideration could be given to providing financial support for construction costs. Additionally, with the revision of emission standards, the costs of sewage treatment plants are likely to increase, necessitating a corresponding increase in collection standards for sewage treatment fees. By basing

fee standards on the operational costs of sewage treatment plants while accounting for emission standards, reasonable fee standards can be formulated for sewage treatment. This approach incorporates the environmental costs of sewage discharge and treatment into the sewage treatment fee system, thereby promoting environmental protection and sewage management. Therefore, the relationship between cost and pricing is reflected in the extent to which the pricing mechanism of sewage treatment fees covers the operating costs of sewage treatment plants, and the implementation of the polluter pays principle. If the pricing of sewage treatment fees can more fully cover the total operating costs of sewage treatment plants and ensure that polluters bear the corresponding costs, it can effectively promote the development of the sewage treatment industry, improve the economic benefits of sewage treatment, and achieve sustainable environmental protection goals.

5.1.2. Sewage Treatment Costs of 36 Large- and Medium-Sized Cities Nationwide

Long et al. [36] investigated the sewage treatment costs of 36 large and medium-sized cities nationwide to determine both the average sewage treatment fees and the disparity between the full sewage treatment costs across the eastern, central, and western regions. Their findings revealed regional variations in full sewage treatment costs. In 2019, these costs ranged from CNY 0.83 to 2.41 per ton across the 36 cities, with an average cost of CNY 1.37 per ton. Notably, the eastern region had the highest full sewage treatment costs, followed by the western and central regions. Presently, in most areas of China, the collected sewage treatment fees struggle to fully cover the total costs of sewage treatment, resulting in shortfalls of approximately CNY 0.31 per ton, CNY 0.27 per ton, and CNY 0.45 per ton for the eastern, central, and western regions, respectively. Therefore, there is a recommendation to gradually increase sewage treatment fee collection standards to ensure they can cover all associated costs. Furthermore, the adoption of an incremental tiered fee system and a differentiated sewage discharge fee mechanism is suggested. Strong financial and tax policy support for the sewage treatment industry, particularly in the western region, is necessary to address the significant gap between sewage treatment fees and costs [37]. In addition, there is a cost inversion between the average sewage treatment fees and the overall sewage treatment costs across the eastern, central, and western regions. From 2011 to 2016, the annual revenue from sewage treatment fees only covered about 60% of annual operating expenses, with fees collected from users accounting for approximately 70% of sewage treatment service fees paid by enterprises, while the remaining 30% originated from financial subsidies from local governments [36]. In 2019, the Ministry of Finance issued the “Management Measures for Subsidy Funds for Urban Pipe Networks and Sewage Treatment” to standardize and strengthen the management of subsidy funds for urban pipe networks and sewage treatment, aiming to enhance the efficiency of financial fund utilization. Funds are allocated based on the investment amount for the 3-year construction tasks reported by western provinces organized by the Ministry of Housing and Urban-Rural Development, utilizing a factor method. Additionally, there is a bias towards the western regions at a ratio of 0.7:1 compared with the same investment amount in other regions.

Table 3 [36] shows the average difference between sewage treatment fees and full sewage treatment costs in the western, central, and eastern regions.

Table 3. Shows the average difference between sewage treatment fees and full sewage treatment.

Region	Operating Costs of Sewage Treatment	Cost of Sludge Treatment and Disposal	Total Cost of Sewage Treatment	Sewage Treatment Fee	Difference between the Sewage Treatment Fee and the Total Sewage Treatment Cost
Western	1.23	0.12	1.35	0.90	−0.45
Central	0.94	0.23	1.17	0.89	−0.27
Eastern	1.16	0.20	1.36	1.05	−0.31

5.2. Unclear Cost Allocation Is Heavily Dependent on Local Finances

The allocation of sewage treatment fees is unclear, and the pricing method for sewage treatment fees is singular, lacking scientifically effective plant-network integrated management. This management approach overlooks the relationships among various stakeholders in sewage treatment, leading to a lack of incentive connections and insufficient interaction between urban areas, resulting in fragmented plant-network management [38,39]. Due to the aging of sewage pipelines, inadequate maintenance, and sewage flushing, urban sewage pipelines exhibit structural and functional defects, including widespread issues such as combined rain and sewage, leakage, corrosion, misalignment, misconnection, deformation, and rupture. While most cities rely on traditional manual inspection and dredging maintenance methods, these have not effectively addressed the serious problems of structural damage, leakage, and diseases in sewage pipelines, resulting in low efficiency. In China, the influent COD concentration of sewage treatment plants typically falls below 300 mg/L, and the BOD5 concentration generally remains below 150 mg/L, significantly lower compared with developed countries [31,40–45].

Overall, the engineering efficiency of China's urban sewage treatment systems remains low, with many urban areas facing incomplete or defective sewage pipelines. A comparative analysis revealed a significant gap in drainage pipeline density. For instance, in developed areas within the administrative districts of U.S. cities in 2002, it was 15 km/km², in Japan it ranged from 20 to 30 km/km² in 2004, while in China it was 11.11 km/km² in 2019. Drainage pipelines are vital infrastructure, with the value of the drainage pipeline network in the U.S. estimated at about one trillion dollars. Furthermore, the drainage pipeline network is essential for sewage collection and the protection of water resources and the environment [46–51]. In addition, issues such as water shortages and external seepage in sewage pipelines are widespread, exacerbated by the fact that sewage treatment fees do not cover sewage collection costs. Currently, partial cost accounting is being used, where sewage treatment fees only cover the processing phase, excluding the collection phase. This results in a missing link in cost distribution, with significant disparities in financial support from local governments in different cities. Hence, there is insufficient regular financial support for sewage in most cities, leading to a substantial shortfall in investment in sewage pipeline construction and operation. These collective issues collectively hinder the normal operation and quality improvement of China's urban sewage treatment systems.

5.2.1. Payment for Sewage Treatment in Various Districts and Counties of Chongqing Municipality

In Chongqing Municipality, the primary burden of sewage treatment costs in townships and towns is still shouldered by the government, while sewage dischargers contribute to the payment. An analysis of the submitted payable sewage treatment fees and the actual collected fees from various districts and counties reveals that the annual operating cost of township sewage treatment is approximately CNY 550 million. Of this, the financial allocation from district and county governments constitutes the majority, amounting to CNY 420 million, while payments from polluters total CNY 130 million. When examining specific districts and counties, Jiangjin incurs the highest annual maintenance cost at CNY 63.25 million, followed by Fengdu at CNY 44.86 million, and Fuling ranking third with an annual maintenance cost of CNY 29.25 million. The operation and maintenance costs of sewage treatment in various districts and counties of Chongqing Municipality are illustrated in Figure 6.

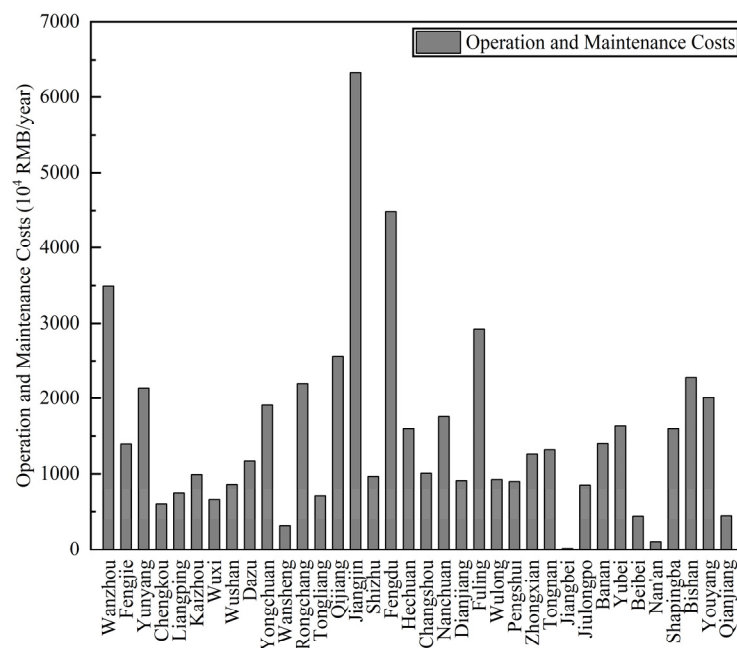


Figure 6. Operating and Maintenance Costs of Sewage Treatment in Various Districts and Counties of Chongqing Municipality.

5.2.2. Sewage Treatment Charges in Various Districts and Counties of Chongqing Municipality

1. The system of “polluter pays” has not yet been fully established.

Across the entire city, towns and townships collect pollution discharge fees from polluters amounting to CNY 130 million annually, leaving a funding gap of about CNY 420 million for current operation and maintenance. Among the 23 districts and counties in the city, sewage treatment fees are implemented for town sewage treatment plants in 13 districts and counties, levying fees on all towns and townships, while the other 10 districts and counties only collect fees for some towns and townships. Conversely, 16 districts and counties do not collect sewage treatment fees from polluters at all. Figure 4 shows the sewage treatment fees in various districts and counties in Chongqing.

2. Single collection channel.

Charges are collected through the water supply company based on the water consumption in the water bill. Three main charging standards are applied: CNY 1 per ton for domestic water, CNY 1.3 per ton for industrial and business water, CNY 1 per ton for residential water, and CNY 1.3 per ton for non-residential water. A uniform rate of CNY 1 per ton is applied.

3. The relevant system is not sound.

Chongqing’s approach to sewage fee collection in towns and townships is notably behind that of other regions. For instance, Hunan Province has taken steps to address this issue by issuing the “Notice on Further Improving the Province’s Policies for Sewage Treatment Fees in Towns and Townships and the Collection and Management System” (Xiang Development and Reform Price Fee No. 29). This notice establishes a dynamic adjustment mechanism for cost-sharing and charging standards, ensuring fairer practices. Specifically, the uniform collection standard has been revised to not less than CNY 0.85 per ton for residential water and not less than CNY 1.20 per ton for non-residential water. The current state of sewage treatment charging across each district and county in Chongqing Municipality is shown in Figure 7.

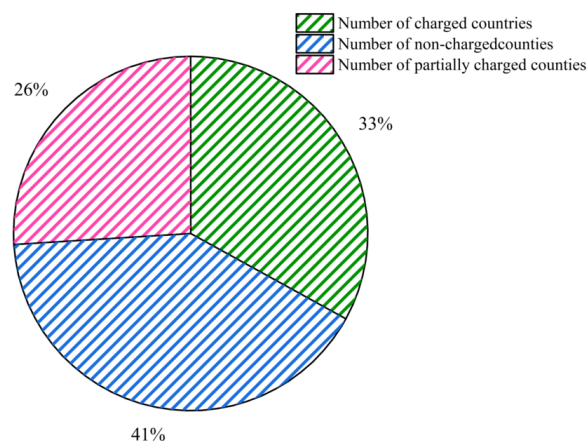


Figure 7. Sewage Treatment Charges in Various Districts and Counties of Chongqing City.

5.3. Insufficient Sewage Treatment Funds

The inadequacy of sewage treatment prices contributes to the wastage of water resources and insufficient investment in infrastructure, resulting in a decline in sewage treatment quality. This inadequacy inevitably exacerbates water pollution and environmental degradation and poses a threat to human health [42,52,53]. The reasons for this situation can be attributed to two main factors: firstly, citizens are reluctant to pay fair prices for public services such as water and sewage treatment; secondly, due to concerns about controlling the core consumer price index (CPI), which includes water and sewage treatment prices, management hesitates to increase prices for water and sewage services, choosing instead to postpone necessary investments [7,54]. In comparison with developed countries, China's sewage treatment infrastructure started relatively late, resulting in significant differences in terms of quantity, scale, penetration rate, mechanization, facilities, and automation level. For instance, the U.S. has the highest number of sewage treatment plants globally, with an average of one plant for every 5000 people, while the United Kingdom has around 8000 sewage treatment plants, serving an average of 7000 people per plant [55,56].

The challenges faced by China's sewage treatment sector can be attributed to the lack of funds, leading to inadequate investment intensity to cover the full cost of sewage treatment. This issue is particularly acute in sludge treatment. During China's "Twelfth Five-Year Plan", sludge treatment received only CNY 34.1 billion in support, representing a mere 8% of the total investment, falling significantly short of the 30–50% standard observed in developed countries, highlighting China's insufficient funding for sludge treatment [51,57]. Figure 8 illustrates that sludge treatment accounts for only about 8% of the total investment.

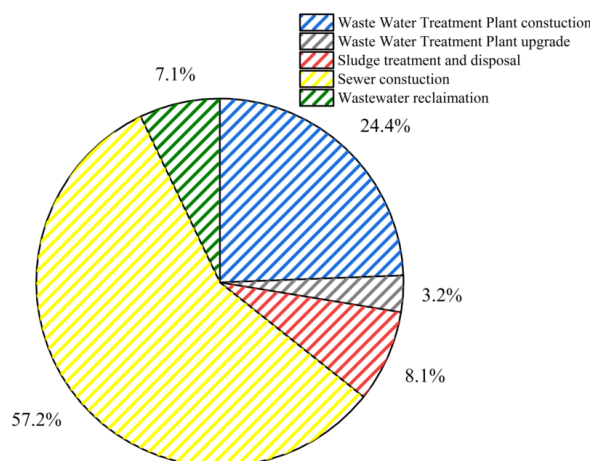


Figure 8. Investments in urban infrastructure projects, including sewage treatment during the "Twelfth Five-Year Plan". Sludge treatment accounts for only 8.1%.

Insufficient Operational and Maintenance Funds for Township Pipe Networks in Chongqing

The construction funding capacity of municipal towns in Chongqing is insufficient as it relies on a single source of operating funds, which makes it challenging to ensure adequate funds for later operation and maintenance. Presently, the operating and maintenance funds for sewage pipelines in Chongqing's towns are severely lacking. In some districts and counties, only CNY 1–1.5 million per year is allocated for the operation and maintenance of sewage pipelines across the entire county. The operating cost per kilometer ranges from CNY 0.2 to 0.5 million per year, which is significantly lower than the CNY 0.8–1.6 million per year allocated for urban sewage networks in Chongqing, indicating a substantial gap. Furthermore, some districts and counties even lack dedicated funds for pipeline maintenance. Qualified pipeline operation and maintenance require regular inspections, cleaning, and upkeep. However, due to insufficient financial support, Chongqing's town sewage pipeline network operates in a reactive mode, addressing issues only as they arise. Operation, maintenance, and management exhibit numerous deficiencies, with minor issues often overlooked until they escalate into major problems. Additionally, the professional level of operation and maintenance for town pipelines is notably low, typically managed by local government personnel, with some districts and counties outsourcing management to local pipeline operation and maintenance enterprises. Special funds for town pipeline maintenance are severely lacking, with some districts and counties allocating only CNY 1.5 million per year to maintain the pipeline network for all towns in the area. Most towns lack dedicated funds for pipeline operation and maintenance, relying on temporary allocations for urgent repairs to sustain normal pipeline network operations. In comparison with the annual operating funds of CNY 8–16 thousand for urban drainage networks, the funding gap for town drainage networks is substantial.

The data and charts in this article were processed and plotted using Microsoft Excel 2019 and Origin 2021 software, respectively.

6. Countermeasures and Suggestions

6.1. Promoting the Integration of Factories and Networks

The assessment method for integrating factories and networks establishes a direct link between sewage treatment fees and influent water pollutants, as well as correlating network maintenance costs with influent water pollutant concentrations. This approach fosters mutual connections between cities and regions while incentivizing stakeholders in operations and management. The implementation of this method involves designing an indicator system, determining target values, specifying assessment payment plans, and defining clear city-district payment ratios. Thus, promoting the integration of factories and sewage treatment networks offers a solution for current sewage management challenges [58].

This integrated mechanism establishes connections between cities and districts, factories and networks, departing from the previous single pricing model. To promote the integration of factories and networks effectively, it is important to periodically optimize and update the indicator system to ensure alignment with the latest environmental standards and technological developments, accurately reflecting the actual situation of sewage treatment and enabling the formulation of more reasonable fee standards. Moreover, implementing a dynamic adjustment mechanism is essential to reflect real-time changes in the sewage treatment levels of cities and regions. Through real-time monitoring and data analysis, target values can be flexibly adjusted. Enhancing transparency is key to ensuring fair and reasonable cost allocation, providing the public with a clear understanding of sewage treatment fee expenditure. Coordinating the construction of pipeline networks with sewage treatment plants ensures the normal conveyance and treatment of sewage. Therefore, integrating factories and networks requires corresponding technical support and personnel training. Efforts should focus on increasing technical training for enterprises and management organizations, and selecting professional teams with sufficient capabilities to operate and maintain the integrated system of factories and networks. This approach

effectively utilizes the comprehensive functions of sewage treatment and collection systems to improve overall operational efficiency [59].

6.2. Increase the Collection Rates of Sewage Treatment Fees

As an effective policy tool, water pricing not only reflects the scarcity of water resources but also helps to stimulate water conservation awareness, promoting a more rational and economical utilization of water resources in society [60–69]. In developed nations, sewage treatment fees are notably high, often constituting a significant portion of the overall water price, ranging from 40% to 60%. For instance, across many OECD member countries, sewage treatment fees typically range from CNY 6.6 to 23 per ton. In certain countries like the United States, Scotland, and Finland, sewage treatment fees surpass 50% of the total water price [70–72]. Considering the full cost accounting principles, it is important to devise comprehensive water pricing policies aimed at enhancing water efficiency, curbing sewage generation, and encouraging the active participation of industrial and municipal sectors in sewage treatment and recycling endeavors. Such initiatives would be pivotal in fostering the sustainable utilization of water resources [73].

The government should actively adjust water prices by issuing robust administrative directives, thereby enhancing public awareness regarding water conservation. Simultaneously, it should advocate for and incentivize the utilization of reclaimed water to ensure more sustainable and efficient management and utilization of water resources throughout society. Moreover, the government should strive to prevent overreliance on local finances for sewage treatment. Instead, it should adhere to the principle of making sewage treatment fees the primary source of revenue, supplemented by financial subsidies, which involves promoting a reasonable increase in sewage treatment fees, elevating their proportion in the overall water price, and raising the sewage treatment fee standards to cover the full cost of sewage treatment.

6.3. Establishing a Cost Model for Sewage Collection and Treatment Systems

As Chinese urban areas continue to develop, traditional sewage treatment facilities may no longer meet the needs of modern cities. Therefore, it is imperative to develop suitable sewage collection and treatment models. This process requires conducting surveys to gather cost data from existing sewage pipeline networks and sewage treatment plant construction systems, taking into account factors such as scale and cost. Decisions regarding centralized versus decentralized systems must be made optimally. When selecting a sewage collection and treatment system, the primary goal should be to minimize the overall system cost while ensuring compliance with emission standards [74].

With urban development in China, traditional sewage treatment facilities are becoming less suitable for modern cities. Thus, there is a need to develop appropriate sewage collection and treatment models. This requires conducting surveys to gather cost data from existing sewage pipeline networks and sewage treatment plant construction systems. Factors such as the scale and cost of sewage pipelines and treatment plants must be considered. Optimal choices between centralized and decentralized systems must be made, aiming to minimize the overall system cost while meeting emission standards. Establishing a cost model for sewage collection and treatment systems, under the premise of meeting sewage discharge standards, is necessary. This involves comprehensive cost analysis, including the construction, maintenance, and operation costs of sewage pipelines and treatment plants. It is important to ensure that the cost model fully considers the actual costs at each stage and is based on reasonable pricing. Maximizing the reduction of investments in new facilities by making full use of existing sewage pipeline networks and treatment plants is essential. Upgrading and renovating existing infrastructure to enhance treatment capacity and reduce the overall system cost should be prioritized. Optimizing the scale of sewage pipelines by reasonably determining capacity based on urban size and water consumption can help reduce construction and maintenance costs. When establishing the cost model, the sustainability and long-term planning of the system

should be considered. Adopting an adjustable cost model to adapt to changes in future urban development ensures the continuous and effective operation of the system.

6.4. Implementing a Differentiated Sewage Treatment Fee Collection Mechanism

Sewage treatment fees are one of the most widely adopted environmental policies to address environmental issues [1,75,76]. The cost of sewage treatment fees can influence the attitudes of polluting enterprises towards environmental management, thereby affecting the strategies adopted by the environmental protection industry. Consequently, sewage treatment fees play a significant role in influencing the behavior of polluting enterprises and impacting the development trajectory of the environmental protection industry. The proper management of the dynamic interplay among environmental policies, the environmental protection industry, and polluting enterprises is essential to achieving an optimal balance [2,77].

Differences in sewage treatment fees across different cities in China are primarily influenced by several factors, such as the size and developmental level of the urban area, the volume of sewage discharged, water quality requirements, geographical conditions, technological investments, and government policies. Developed cities typically have advanced treatment facilities and management systems, with substantial investments in technology and infrastructure. Conversely, smaller or economically underdeveloped areas may lag in these aspects. Additionally, differences in sewage discharge volumes and water quality standards, as well as geographical and environmental factors, influence the selection of treatment methods and fee levels. Government policies and management systems also play a significant role in determining sewage treatment fees. For instance, subsidy policies may alleviate the financial burden on residents, while certain local governments may impose higher fees on residents. Overall, the variations in sewage treatment fees stem from the combined impact of these multiple factors.

Significant differences exist in the emission fee standards established by local governments across diverse regions and within the environmental protection industry's varying levels of development. Government policies can exert considerable influence on the industry's development model. When formulating the sewage treatment fee system, it is essential to consider factors beyond the type and scale of pollutants. Developing a differentiated sewage treatment fee collection mechanism requires a comprehensive evaluation of each region's economic development level and environmental quality. Introducing a benchmark system, drawing on benchmarks from various industries and regions, serves as the basis for fee standards, ensuring their reasonableness and acceptability. Additionally, implementing a dynamic adjustment mechanism involves regularly assessing and adapting fee standards to align with local environmental conditions. To incentivize enterprises to actively participate in the development of the environmental protection industry, a pollution responsibility incentive mechanism is proposed, which entails imposing moderate penalties on enterprises that exceed emission standards and rewarding those that voluntarily adopt environmental protection measures, thus fostering a positive competitive environment. Throughout the entire system design process, social participation and transparency are vital. Seeking input from various stakeholders, including environmental organizations, businesses, and the public, ensures system openness, enhances societal involvement, and reduces disputes and dissatisfaction. This integrated approach reflects a balanced relationship between environmental protection and economic benefits under a differentiated sewage treatment fee system. Therefore, it is suggested that different regions adopt different sewage treatment fee collection standards based on their respective economic development levels and current environmental quality conditions [78–81], whereby higher pollution would lead to higher fees.

6.4.1. Impact of Sewage Treatment Fee Pricing on Residents of Traditional Agricultural Product Processing Villages in the Nhue-Day River Basin of Vietnam

Trang et al. [82] conducted a study in three traditional agricultural product processing villages located in Yangliao, Xinhe, and Fudu communes within the Huai Duc, Quoc Oai, and Thach That districts of Hanoi using the Contingent Model (CM) method and the Choice Experiment (CE) technique to assess the willingness to pay (WTP) for sewage treatment fees among 267 selected agricultural product-processing households. The findings revealed that approximately 64.8% of the respondents recognized the advantages of sewage treatment. On average, households were willing to pay VND 100,610 per month for sewage treatment project environmental fees before discharging sewage into rivers in Hanoi. As policy priorities increasingly focus on enhancing environmental conditions, households' willingness to pay is expected to rise accordingly. Both national and local governments have devised plans to mitigate environmental pollution and rehabilitate watershed ecosystems through the construction and refurbishment of wastewater collection and treatment systems. As long as the economic benefits outweigh the associated costs, efforts to enhance water environments are anticipated to enhance the well-being of the populace.

6.4.2. Impact of Sewage Treatment Fee Pricing on Residents of Wenchang City, Hainan Province

In October 2023, the government of Wenchang City, Hainan Province, introduced the "Wenchang Urban Sewage Treatment Fee Collection Standard Plan". Under this plan, the sewage treatment fee in Wenchang City was suggested to be set at a minimum of CNY 0.95 for residents and CNY 1.4 for non-residents. Moreover, to safeguard the basic living standards of low-income families and economically disadvantaged individuals, a subsidy of CNY 0.35 per ton of sewage treatment fee will be provided. The funds collected from sewage treatment fees would be allocated to maintain and ensure the regular operation of sewage treatment facilities, enhance the quality of household water, and mitigate environmental pollution. This initiative not only contributes to addressing water environmental pollution but also fosters a favorable living environment, enhancing the quality of life for Wenchang City residents. Furthermore, it promotes energy conservation, emission reduction, and water pollution prevention, thus safeguarding the ecological environment and facilitating sustainable socio-economic development in the city.

As a fundamental public service infrastructure, sewage treatment is essential for urban residents, and sewage treatment fees represent the cost residents must bear to access this service. Adjustments to sewage treatment fees directly impact residents' water bills, inevitably prompting concerns among the general population. Inappropriate adjustments may lead to objections from residents, posing challenges to the smooth implementation of the adjustment process.

6.5. Establish a Comprehensive Cost-Based Sewage Pricing Mechanism

It is suggested that the government should adopt the PPP model more flexibly, optimizing its structure to maximize the implementation of the "polluter pays" principle and alleviate financial burdens. Considering the overall cost of sewage treatment comprehensively, China must adjust the cost accounting principles to ensure that sewage treatment fees cover sewage collection costs, achieving comprehensive cost coverage across all stages. Simultaneously, establishing a reasonable cost allocation mechanism to ensure efficient resource utilization is essential. In addition, the government could formulate relatively uniform financial support policies, narrowing fiscal gaps between cities. Additionally, a normalized funding support mechanism can be established to ensure continuous financial support for urban sewage treatment systems and promote the construction and operation of sewage networks. Introducing a sewage treatment fee collection mechanism into the sewage collection system would also ensure that users pay fees at this stage, achieving comprehensive coverage of sewage treatment costs with sewage treatment fees and enhancing the economic feasibility of sewage collection systems through incentive policies.

Moreover, adjusting the direction of social capital investment, increasing investment in sewage collection systems, establishing a more balanced factory-network integrated project, and reducing the occurrence of “investment in the factory but not in the network” situations are also essential. As sewage treatment fees currently only cover the treatment process and not the collection process, it is recommended to clarify that sewage treatment fees can be used for the construction, operation, and sludge treatment disposal of sewage collection facilities and centralized sewage treatment facilities. Introducing judicial interpretations to clarify that centralized sewage treatment facilities include sewage collection systems will integrate them within the definition of urban centralized sewage treatment facilities. This adjustment permits sewage treatment fees to be utilized for sewage collection network systems. Simultaneously, it is essential to amend the relevant laws to broaden the scope of the sewage treatment fee application, renaming it as sewage collection and treatment fees. This legal adjustment provides support for enhancing the pricing mechanism of sewage collection systems [29,63,83].

7. Conclusions

With China continuously raising sewage treatment standards, the widening gap between sewage treatment fees and actual costs poses a threat to the sustainable development of China’s sewage treatment industry. The main issues with sewage treatment fees include an incomplete pricing system, insufficient funds, unclear cost allocation, and a heavy dependence on local finances. Addressing these challenges requires future research to focus on achieving a comprehensive cost-coverage sewage treatment pricing mechanism, aiming for the comprehensive coverage of full sewage treatment costs. To tackle the incomplete pricing system, the implementation of factory-network integration emerges as a solution. Such an approach establishes connections between cities and districts, factories, and networks, linking sewage treatment fees to incoming water pollutants and network maintenance costs to incoming water pollutant concentrations. This helps resolve issues such as fee-price separation and fragmented management. Implementing factory-network integration necessitates a scientifically effective indicator system and a flexible dynamic adjustment mechanism to ensure alignment with the latest environmental standards and technological advancements. To address insufficient funds, it is necessary to increase the prices of sewage treatment fees. Government adjustments to water prices and the establishment of a full-cost sewage pricing mechanism can ensure that fees cover all costs while incentivizing businesses and municipal departments to actively engage in wastewater treatment and recycling efforts. To avoid excessive reliance on local finances, adhering to the “polluter pays” principle and promoting a reasonable increase in sewage treatment fees are essential. Establishing a cost model for sewage collection and treatment systems, along with introducing a differentiated sewage treatment fee collection mechanism, is essential. This involves fully considering differentiated needs in various regions and establishing differentiated collection standards based on comprehensive assessments of economic development levels and environmental quality to ensure the reasonableness and acceptability of fees. Introducing a pollution-responsibility-driven mechanism through rewards and penalties for enterprises can foster a positive competitive environment and encourage businesses to actively participate in the development of the environmental protection industry. Lastly, establishing a full-cost sewage pricing mechanism is recommended, ensuring comprehensive accounting by adopting PPP models more flexibly and optimizing the structure. Simultaneously, formulating a relatively unified fiscal support policy and establishing normalized funding support mechanisms are important to ensure continuous financial support for urban sewage treatment systems and promote the construction and operation of sewage networks.

In summary, by implementing factory-network integration, increasing sewage treatment fee collection prices, establishing a cost model for sewage collection and treatment systems, implementing a differentiated sewage treatment fee collection mechanism, and establishing a full-cost sewage pricing mechanism, China’s sewage treatment industry

could achieve healthier and more sustainable development. This approach would provide a balance between environmental protection and economic benefits. Formulating a reasonable and scientific sewage treatment pricing mechanism and promoting the development of the sewage industry should consider various factors, such as social and economic aspects, necessitating further in-depth research.

Author Contributions: Conceptualization, G.Z. and Z.M.; methodology, Y.H.; software, L.C.; validation, D.S., X.L. and L.C.; formal analysis, Y.H.; investigation, G.Z. and Z.M.; resources, G.Z.; data curation, D.S. and X.L.; writing—original draft preparation, Z.M.; writing—review and editing, X.L.; visualization, D.S.; supervision, Y.H.; project administration, X.L.; funding acquisition, D.S. All authors have read and agreed to the published version of the manuscript.

Funding: This work was financially supported by the National Natural Science Foundation of China, grant number (51808086); the Natural Science Foundation of Chongqing, China (CSTB2022NSCQ-MSX1145); and the Chongqing Bayu Scholars Young Scholars Project (YS2021089); Chongqing Technology Innovation and Application Development Project (CSTB2022TIAD-KPX0133). The scientific research project of Chongqing Municipal Urban Management, “Research on Innovative Technology of Microbial Ecological Management of Eutrophic Water Bodies in Chongqing” [Urban Management Ke Zi 2023 No. 02], Chongqing Water Conservancy Science and Technology Project [Grant No. CQSLK-2023002]; Postgraduate Innovation Program of Chongqing University of Science and Technology (YKJCX2320609); Special Grant for Postdoctoral Research Projects in Chongqing Municipality in 2023 (231101353029024).

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

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