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Evaluation on the Implementation of Industrial Water Pollution Control in China

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Abstract: The provisions of industrial water pollution prevention and control have been well implemented since the newly revised *Law of the People's Republic of China on the Prevention and Control of Water Pollution* was issued on January 1, 2018. National policies and facility construction related to industrial water pollution prevention and control have made substantial progress. National departments and provinces have issued more than 60 policies and regulations. Outdated production facilities were eliminated to promote cleaner production, and over 1400 centralized sewage treatment facilities were constructed in industrial gathering areas. However, investigation and evaluation imply slow progress in the implementation of some legal provisions and control of industrial water pollution. Moreover, the implementation of provisions between regions and industries is imbalanced, excessive pollutant discharge occurs, and the regulatory capacity to support new national/local emission standards is insufficient. We suggest implementing whole-process control for industrial water pollution while focusing on cleaner production, as well as optimizing drainage indicators to further promote environmental information disclosure.

Keywords: prevention and control of water pollution; industrial water pollution; prevention and control measures; engineering measures; cleaner production; information disclosure

1 Introduction

China is in a rapid development stage of industrialization, informatization, and modernization; consequently, the task of water pollution prevention and control has become arduous. Prevention of water pollution is essential for ecological civilization. Since the 18th National Congress of the Communist Party of China, the State Council has issued the *Action Plan for Prevention and Control of Water Pollution* ("Ten Water Articles") on April 2, 2015 and has revised the *Law of the People's Republic of China on Prevention and Control of Water Pollution* (*Law on Prevention and Control of Water Pollution*) on June 27, 2017. Furthermore, following the 19th National Congress of the Communist Party of China, the National Eco-Environmental Protection Conference was held on May 18–19, 2018. On June 16, 2018, the *Opinions on Comprehensively Strengthening Eco-environmental Protection and Resolutely Fighting the Battle of Pollution Prevention and Control* was issued, proposing that efforts should be made for the provision of clear water and rapid remediation of pollution source systems, such as industries. The nationwide battle to prevent and control pollution is one of the three major battles to build a moderately prosperous society. Recently, a series of important environmental protection measures introduced by the state, such as excellent pollution control, frequent introduction of systems, strict supervision and enforcement standards, and unprecedented speed of environmental quality improvement, have promoted a historic transition and overall changes in ecological environmental protection.

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In 2018, China's water consumption per 10 000 CNY GDP was 66.8 m^3, and the water consumption per 10 000 CNY of value added by industry was 41.3 m^3, which was approximately twice that of the world's advanced level water consumption [1]. Among the three major industries in the national economy, China's secondary industry has consistently accounted for approximately 40% of its GDP [2]. Industrial growth is one of the main driving forces behind the rapid economic growth of China; however, industries have also contributed to extensive environmental pollution. Compared with developed countries, which are dominated by the service industry, China has made outstanding achievements in terms of the total amount and speed of economic growth. However, growth is predominantly determined by the input of resources. From the perspective of industrial structure, the chemical, metallurgical, energy, food processing, and other heavy chemical industries occupy an important position among the total output values of industrial enterprises above a designated size. Consequently, the discharge of sewage is large, and pollutants, such as chemical oxygen demand (COD) and ammonia nitrogen, account for more than 70% [3] of the total pollutants. The production structure characterized by high energy consumption, high pollution, and poor technology determines China's export role in the international division of labor, which is limited by low efficiency, insufficient output value, and high emissions. China's COD discharge per unit area is higher than that of developed countries such as Japan [3,4]. Although the total amount of industrial wastewater discharge in China has maintained a slow downward trend in recent years, it is reasonable to think that this trend will continue with the pace of industrial transformation and technological upgrading. Compared with developed countries, the total amount of industrial pollution discharge in China is still high. The emission intensity must be reduced, which is considerably different among various regions and industrial departments.

On January 1, 2018, the newly revised *Law on Prevention and Control of Water Pollution* was officially implemented. Evaluating the implementation of the *Law on Prevention and Control of Water Pollution* is important for implementing *The Decisions of the Central Committee of the CPC and the State Council on Comprehensively Enhancing Eco-environmental Protection to Completely Win the Battle Against Pollution*. The present study evaluates the implementation of the legal provisions of industrial water pollution prevention and control in Chapter IV, "Water Pollution Prevention and Control Measures" of the *Law on Prevention and Control of Water Pollution*; investigates the implementation of industrial water pollution prevention and control measures in 2018–2019; examines the specific implementation measures in industrial water pollution prevention and control systems, norms, technologies, and projects; addresses problems and limitations; analyzes the main reasons; and proposes future countermeasures. Moreover, this study provides crucial support for comprehensively improving the supervision level for the implementation of the *Law on Prevention and Control of Water Pollution*, promoting the green transformation of the industry, and achieving the goal of water pollution control.

2 Evaluation of the industrial water pollution prevention clause in the *Law on Prevention and Control of Water Pollution*

2.1 An overview of the provisions

In 2017, the newly revised *Law on Prevention and Control of Water Pollution*, Chapter IV, Water Pollution Prevention Measures, Section II, industrial water pollution prevention covered articles 44–48, including five articles and ten paragraphs (Table 1), of which Article 45 is a new clause, whereas the other seven articles are reserved clauses. The new clauses primarily include the classified collection and treatment of toxic and hazardous pollutants in industrial wastewater, construction and automatic monitoring of facilities in the gathering area, and sewage pretreatment. The present study aimed to comprehensively prevent and control industrial wastewater, as well as prevent the dilution and discharge of toxic and hazardous water pollutants. The reserved clauses primarily include industrial pollution prevention and control, such as eliminating backward production capacity, banning seriously polluting enterprises, and promoting cleaner production and technological transformation. In general, the provisions on the prevention and control of industrial water pollution are effectively associated with the *Environmental Protection Law of the People's Republic of China* revised in 2014 and the *Cleaner Production Promotion Law of the People's Republic of China* revised in 2012.

2.2 Overall evaluation

The general implementation of industrial water pollution prevention and control clauses and regulations has been favorable (Table 1). Many studies have been conducted on the formulation and implementation of relevant policies and regulations and the implementation of water pollution prevention and control engineering measures; nevertheless, there is a problem of unbalanced implementation among clauses in different regions and industries.

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With the introduction of Article 45, the sense of responsibility and initiative of relevant departments, local governments, and enterprises in the implementation of industrial wastewater collection and treatment measures has been strengthened. Efforts have been made to formulate policies and regulations, implement engineering measures, and supervise the implementation of these measures to enhance industrial water pollution prevention and control. In 2018, 31 provinces (autonomous regions and municipalities) and the Xinjiang Production and Construction Corps formulated policies and measures considering the newly added Article 45 and issued 19 local policies and regulations [5], accounting for 76% of the total number of industrial water pollution prevention and control policies. Twenty one provinces (autonomous regions and municipalities) and the Xinjiang Production and Construction Corps focused on constructing centralized sewage treatment facilities in industrial gathering areas, upgrading sewage treatment facilities, and promoting engineering facilities adapted to local conditions. This has played a positive and influential role in promoting centralized remediation of emissions in industrial parks and has effectively guided the implementation of the newly added Article 45.

Table 1. Overall evaluation of the implementation of industrial water pollution prevention and control clauses.

Clause number	Core content of the clause	Type	Overall evaluation
Article 44	Properly plan the location of industries and reduce the discharge of wastewater and pollutants.	Reserve	Good
Article 45	Classified collection and treatment of toxic industrial wastewater.	Newly added	Common
	Facilities for centralized sewage treatment and monitoring networks should be built in industrial gathering areas.		Good
	Pretreatment of industrial wastewater discharged to centralized sewage treatment facilities should be conducted.		Common
Article 46	The state shall implement a system for eliminating outdated technologies and equipment.	Reserve	Good
	The state announces the list of processes and equipment prohibited within a time limit.		Good
	Stop the production/sale/import/use of the equipment in the list within the specified time limit.		Good
	The eliminated equipment shall not be transferred to others for use.		Good
Article 47	It is prohibited to construct new small-scale production projects that do not conform to the national industrial policies.	Reserve	Good
Article 48	Enterprises shall employ clean technologies to reduce the discharge of water pollutants.	Reserve	Good

3 Implementation effects of industrial water pollution prevention and control in China

3.1 The prevention and control of industrial water pollution has been further strengthened

3.1.1 National departments and local governments promptly formulate supporting policies and regulations

Since the promulgation of the *Action Plan for Prevention and Control of Water Pollution*, various state departments and local governments have issued more than 60 policies and regulations to guide the overall prevention and control of industrial water pollution. The Ministry of Ecology and Environment, the Ministry of Industry and Information Technology, and other ministries and commissions have issued the *Notice on Strengthening the Prevention and Control of Nitrogen and Phosphorus Pollution from Stationary Pollution Sources*, as well as more than 40 other industrial pollution prevention policies, technical guidelines, and norms, which have played an important guiding role in the prevention and control of industrial water pollution. Thirty one provinces (autonomous regions and municipalities) and the Xinjiang Production and Construction Corps have formulated and issued 25 local policies and measures, including *Catalogue of Prohibitions and Restrictions on New Industries in Beijing (2018 Edition)*, *Special Remediation Plan for Water Pollution in Industrial gathering Areas in Liaoning Province*, and *Chemical Pollution Remediation Work Plan for Yangtze River Economic Belt in Jiangsu Province* [5], among which 19 are discharge policies for industrial gathering areas, and six are industrial pollution control policies, such as industrial structure remediation and cleaner production technology transformation (Fig.1).

3.1.2 Departments at all levels continue to eliminate backward production capacity

The production scale and technical levels of different enterprises in China are markedly different. Remediation of the industrial structure is a priority for small, scattered, and polluted enterprises. Departments at all levels

continued to intensify industrial restructuring, banned many enterprises with high energy consumption and pollution and low production, and regulated total production capacity. For example, in 2018, the Ministry of Industry and Information Technology, together with relevant departments, strictly controlled the new production capacity of industries with high water consumption and high emissions, eliminated excess steel production capacity by more than 3×10^7 t, and realized the inter-provincial replacement of more than 4×10^7 t of electrolytic aluminum production capacity [6]. According to statistics, in 2018, 31 provinces (autonomous regions and municipalities) and the Xinjiang Production and Construction Corps cleaned up more than 5000 small and scattered enterprises with heavy pollution, closed down and banned more than 1800 sewage outlets, and relocated more than 3700 industrial enterprises [5].

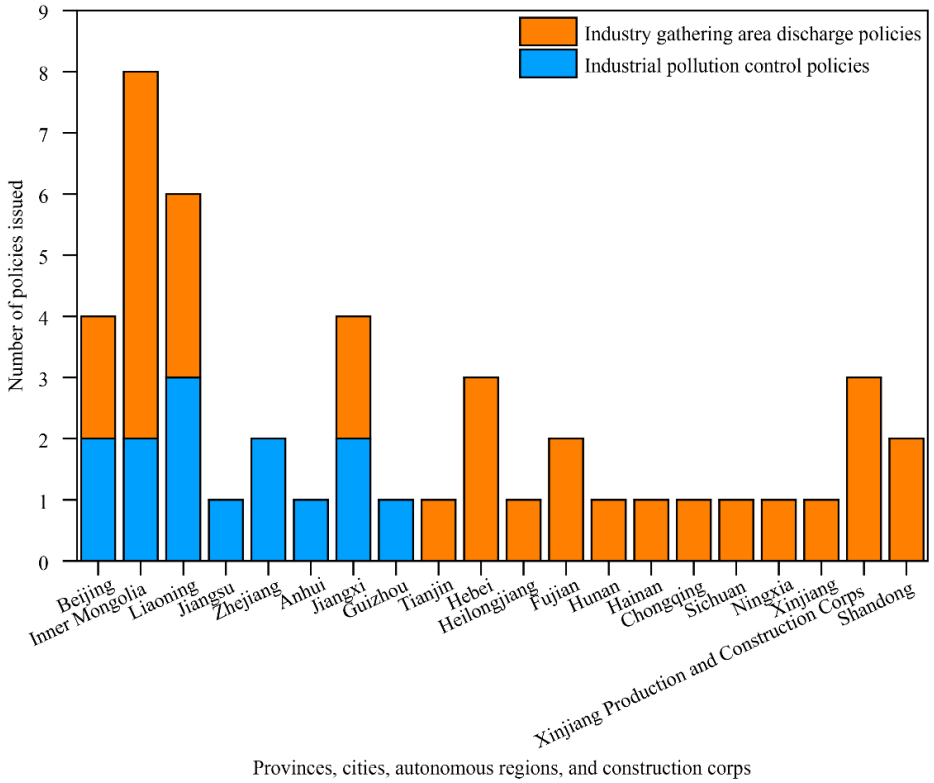

Fig.1. Number of policies released on industrial water pollution prevention and control in provinces, autonomous regions, cities, and construction corps in 2018.

3.1.3 Continued implementation of engineering initiatives

According to the requirements of the centralized treatment of industrial wastewater in the new provisions of the *Law on Prevention and Control of Water Pollution*, departments at all levels take active actions to effectively support centralized treatment and monitor sewage in industrial gathering areas. By the end of 2018, among the 2411 industrial parks at or above the provincial level involved in wastewater discharge, more than 97% had built centralized sewage treatment facilities and installed automatic online monitoring devices, which is 40% higher than before the implementation of the *Action Plan for Prevention and Control of Water Pollution* [7]. The national key pollution source monitoring data management system has also been officially networked, and more than 20 000 enterprises have connected to the management platform. According to incomplete statistics, in 2018, all provinces (cities) in China completed over 1400 centralized sewage treatment facilities in industrial gathering areas (Table 2) [5].

Table 2. Implementation of engineering initiatives in provinces and cities [6]

Implementation effect	Province/city/industry	Engineering quantity/initiatives
Centralized treatment facilities in industrial parks	22 provinces and cities	>1400 items
2411 provincial and above industrial gathering areas	–	>97%
National key pollution source monitoring data networking	–	20 000
Pollutant discharging license	18 industries	>39 000
Banning ten types of small enterprises	15 provinces and cities	>5000

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3.1.4. Active promotion of the transformation and upgradation of clean technology

Under the guidance of laws and regulations, such as the *Cleaner Production Promotion Law of the People's Republic of China* and the *Action Plan for Prevention and Control of Water Pollution*, relevant departments, local governments, and enterprises in the State Council took the initiative to improve the level of industrial pollution control through source prevention, process reduction, and waste recycling. The Ministry of Ecology and Environment has promoted the prevention and control of "three phosphorus" (phosphate rock, phosphorus chemical enterprise, and phosphogypsum warehouse) pollution in the Yangtze River Economic Belt in an orderly manner and announced the completion of clean technological transformation tasks in six key industries, including paper making, steel, and pharmaceutical industries. According to the statistics of materials reported by provinces in 2018, 23 provinces (autonomous regions and municipalities) and the Xinjiang Production and Construction Corps carried out technological transformation in key industries, such as paper making, steel, nitrogen fertilizer, printing, and dyeing. Thirteen provinces (autonomous regions and municipalities) carried out cleaner production, which improved the cleaner production levels of enterprises in key industries [5].

3.2 The system of cleaner production policies and regulations has been continuously improved

At present, a relatively complete top-down cleaner production policy and regulation system has been established and formed, which provides policy support and legal guarantees for the comprehensive development of cleaner production in China.

Since the introduction of the concept of cleaner production, China's cleaner production work has gradually shifted from policy research to policy formulation through pilot implementation. On June 29, 2002, the *Cleaner Production Promotion Law of the People's Republic of China* (hereinafter referred to as the Promotion Law) was promulgated, which allowed China's cleaner production work to enter a stage governed by various laws. Since 2003, with the promulgation and implementation of the Promotion Law, the relevant state departments have successively formulated and promulgated a series of supporting policies and systems, such as *Opinions on Accelerating the Implementation of Cleaner Production*, *Interim Measures for Cleaner Production Audit*, *Provisions on Cleaner Production Audit Procedures of Key Enterprises*, *Notice on Further Promoting Cleaner Production of Key Enterprises*, and *Interim Measures for the Management of Special Funds for Cleaner Production of the Central Government*, which guarantee further promotion of cleaner production. On July 1, 2012, the newly revised Promotion Law was officially implemented, which indicated that the strategy of source prevention and whole-process control had been integrated into the comprehensive strategy of economic development. On July 1, 2016, *the Measures for Cleaner Production Audit* were officially implemented, which further standardized cleaner production audit procedures and better guided local enterprises to carry out cleaner production audits.

Since the promulgation and implementation of *the Measures for Cleaner Production Audit*, the Ministry of Ecology and Environment and the National Development and Reform Commission jointly issued *the Guidelines for Cleaner Production Audit, Evaluation, and Acceptance* in 2018. In 2019, relevant ministries and commissions improved the evaluation index system of cleaner production in the industry, such as the *Evaluation Index System of Cleaner Production in Steel Industry* and the *Evaluation Index System of Cleaner Production in Printing Industry*. Additionally, with the support and guidance of national policies, various provinces (autonomous regions and municipalities) have successively formulated and issued supporting policies and systems, such as the *Regulations on the Promotion of Cleaner Production* and the *Measures for the Administration of Cleaner Productio*n, which have guaranteed cleaner production in various regions.

4 Challenges of industrial water pollution prevention and control in China

As a global manufacturing giant, China's large-scale resource-processing industries, such as the chemical, metallurgy, and textile industries, have long occupied an essential position in the national economy. However, the long-term discharge and accumulation of industrial pollution have caused severe damage to China's water resources and environment, which has become a bottleneck affecting the realization of China's national strategic goal of ecological civilization construction. Based on a comprehensive investigation and practical experience, the major challenges in the prevention and control of industrial water pollution in China are as follows:

4.1 The treatment of industrial wastewater is ineffective, and pollution over the discharge standard occasionally happens

4.1.1 Different natural conditions and economic development levels lead to schedule variance in implementing water pollution prevention measures

The natural conditions and economic development levels of different regions in China differ considerably, which leads to different progress in the implementation of water pollution prevention measures. There are variances in the implementation of clauses across different regions of China. The reserved clauses are better than the new clauses, and the economically developed regions are better than the underdeveloped ones. For example, Zhejiang Province compiled and implemented the *Thirteenth Five-Year Plan for the Prevention and Control of Industrial Pollution in Zhejiang Province* and carried out a final evaluation of the improvement of six heavily polluting and energy-intensive industries, including the chemical industry, printing and dyeing, paper making, tanning, lead storage battery, and electroplating, and reported the evaluation results. However, some industrial water pollution controls in a few provinces (cities) are seriously lagging behind and even notified by the Ministry of Ecology and Environment that there is "incorrect" implementation of the task. Illegal acts, such as industrial enterprises exceeding the standard and the total discharge amount occasionally occurs. Many village-level industrial parks gather several small workshop-style factories. For example, in 2018, the Ministry of Ecology and Environment notified 291 enterprises that water-related pollutants were substantially discharged (Fig. 2) [8–11], of which 56 key pollutant discharge units were in the Xinjiang Uygur Autonomous Region, accounting for 19% of the country, and 32 key pollutant discharge units were in Liaoning Province, accounting for 11% of the country. In November 2018, the Second Central Eco-environmental Protection Inspector Group found that Shanxi Province failed to promote upgrading of the coking industry, and the problem of quenching water over the discharge standard was very prominent. The coke quenching water of 85% of the coking enterprises during the spot check exceeded the standard, and the volatile phenol of 75% of the coking enterprises exceeded the standard, with an average exceeding the standard of 174.3 times.

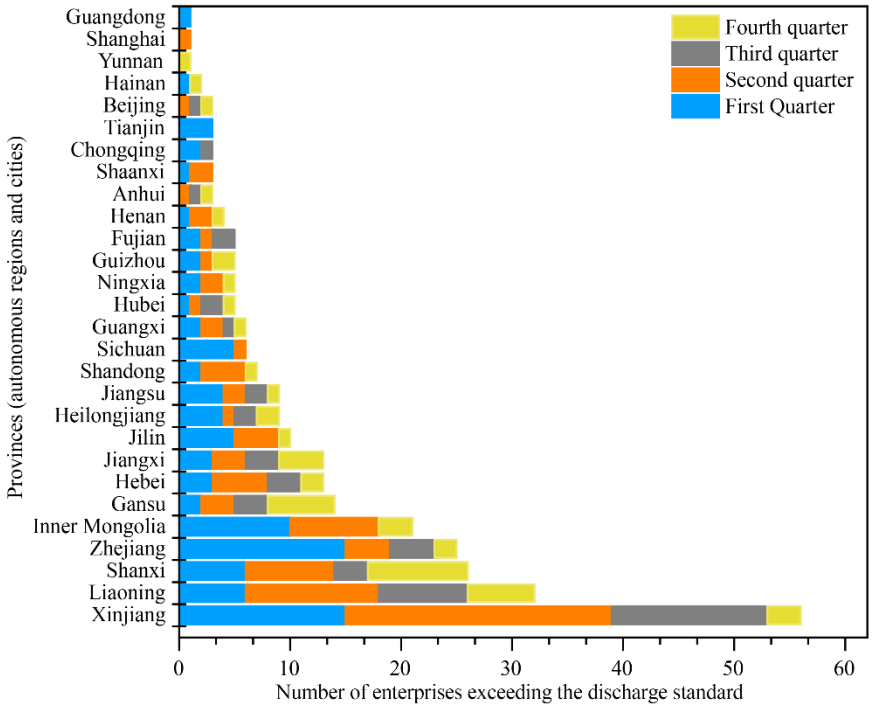

Fig. 2. Number of units notified by the Ministry of Ecology and Environment in 2018 that the discharge of water-related pollutants seriously exceeded the standard.

4.1.2 Industrial differences lead to uneven implementation of water pollution prevention and control measures

Differences in industry distribution, energy conservation and emission reduction technologies, and environmental management capabilities have also led to a certain imbalance in the implementation process of relevant provisions. Overall, the degree of implementation of concentrated industries, such as petrochemicals and

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steel, is better than that of dispersed industries, such as fine chemicals. Fourteen provinces (autonomous regions, municipalities, and corps) have deployed measures, such as clean transformation, sewage permit issuance, and elimination of backward production capacity in related industries. However, pesticides, fine chemicals, and other industries have scattered production capacities, difficult pollution prevention and control, low economic benefits, and implementation lags. For example, the Ministry of Industry and Information Technology has taken the lead in implementing water efficiency "leaders" in key industries such as steel, paper making, textile, and chemical industries, accelerated the popularization and application of advanced and applicable water-saving technologies, and effectively promoted the improvement of water efficiency in key water-consuming industries. As a typical industry with a high production capacity and low difficulty in pollution prevention and control, the steel industry's consumption per ton of molten steel decreased by 15.38% in 2018, based on 18.95% in the *Twelfth Five-Year Plan*, reaching 2.75 m^3 [12,13]. However, enterprises in some industries lack entry into industrial parks, industrial distribution planning is backward, and the agglomeration effect is poor, leading to centralized pollution control not being possible, which requires further optimization.

4.1.3 Insufficient technical support and planning of enterprises and parks, resulting in drainage that cannot meet the standard stably

Thirty-one provinces (autonomous regions and municipalities) and the Xinjiang Production and Construction Corps reported that wastewater treatment in enterprises and industrial gathering areas could not meet the standards stably [5]. An in-depth investigation shows that one of the critical reasons is that there are many kinds of refractory pollutants with high concentrations, strong toxicity, poor biodegradability, and unstable operation of facilities in industrial wastewater from chemical, printing and dyeing, pharmaceutical, and other industries. However, enterprises and industrial gathering areas currently mainly adopt low-cost wastewater biochemical treatment facilities, which make it challenging to meet the design requirements. When enterprises in industrial gathering areas indirectly discharge wastewater after pre-treatment, the treatment efficiency of comprehensive sewage treatment facilities is easily affected, resulting in substandard treatment. Compared to developed countries, China's water pollution control indicators have long focused on COD and ammonia nitrogen. The central part of wastewater treatment in heavily polluted industries is the end-of-pipe treatment. Under the guidance of this policy, many comprehensive sewage treatment plants have been established using multi-strand wastewater mixed treatment, ignoring the water quality, saving investment, simplifying the process, and reducing land occupation. When dealing with industrial wastewater with considerable variations in water quantity, complex chemical composition, and high concentrations of toxic and hazardous substances, the effect of comprehensive treatment plants often fails to reach the expected effect because there are no effective means to control toxic substances. There is no economic and applicable treatment process for high-concentration organic wastewater in the light, chemical, pharmaceutical, and other industries, and refractory organic wastewater in the printing and dyeing, chemical, petrochemical, metallurgy, and coal chemical industries.

4.1.4 The disconnection between the end-of-pipe treatment of wastewater and the production process causes a high cost of pollution treatment

Europe, the United States, and other developed countries promoted industrial resource conservation and technological ecological upgrading and built a resource-saving, comprehensive industrial structure and technology system. In the 1970s, the energy consumption per unit GDP decreased by more than 20% [14]. In recent years, China has dramatically reduced environmental pollution through end-of-pipe treatment and its achievements have been affirmed. However, the environmental pollution treatment mode of end-of-pipe treatment alone can no longer solve the energy saving and environmental protection problems faced by key industries in China. On one hand, wastewater treatment is out of touch with the production process, with less discharge reduction in the production process. All pollutants produced in the workshop sections of the production process were collected at the end of the centralized treatment and then discharged. The treatment cost correspondingly increases, often exceeding the affordability of enterprises. Therefore, the phenomenon of stealing and missing reports on industrial wastewater is more serious. On the other hand, the existing water pollution control system lacks collaborative consideration of the circulation of materials and resources in the production process, leading to high water consumption and cost. The average treatment cost of industrial wastewater in China rose from 1.26 CNY/t in 2011 to 1.7 CNY/t in 2017, and it is expected to continue to rise in the future [15].

4.2 Insufficient regulatory capacity to support the new national/local sewage discharge standards

4.2.1 The standards for supervising toxic and hazardous substances need to be optimized

Under the national policy guidance, the discharge of conventional pollutants from industrial wastewater in China has been controlled to some extent. However, the problem of high environmental risks in highly toxic discharge industries has become increasingly prominent. The intensity of industrial sewage discharge in China is high, especially the toxic and hazardous pollutants from the raw materials of residual toxic chemicals and the production process entering the wastewater, which leads to the complex composition of contaminants in the external drainage and high toxicity risk. Currently, the supervisory list, control methods, and online monitoring of toxic and hazardous water pollutants in China cannot meet the urgent needs of rapid social development. In recent years, many new/revised national and local sewage discharge standards have added toxic and hazardous pollutants ranging from several to more than 100. On July 24, 2019, the Ministry of Ecology and Environment and the Health and Wellness Commission jointly formulated and published the *List of Toxic and Hazardous Water Pollutants (First Batch)* [16], only 10 toxic and hazardous pollutants were published. Many characteristic contaminants involved in the industrial sewage discharge standards promulgated by the state have not yet entered the list, which has affected the implementation of further treatment and regulatory measures. Moreover, due to the lack of monitoring methods and inadequate wastewater treatment facilities, many discharge standards are difficult to implement strictly. For example, there are as many as 109 types of pollution indicators in the newly revised *Shanghai Integrated Wastewater Discharge Standar*d (DB31/199-2018) in 2018, and as many as 67 kinds of organic pollutants in the *Pollutant Discharge Standard for Petrochemical Industry* (GB 31571-2015) [18], including dioxins, benzopyrenes, and polycyclic aromatic hydrocarbons.

4.2.2 Lack of disclosure of industrial pollution data and supervision

In recent years, data on pollutants in industrial wastewater in China, particularly toxic pollutants, have not been publicly declared. It is impossible to query from official documents, such as the *Yearbook of Environmental Statistics*. There are some problems, such as delayed release, low update frequency, lack of data, inconvenient query of release methods, and the lack of disclosure of pollutant discharge amount and concentration, which possess a certain degree of obstacles to the effective evaluation of China's industrial pollution status. In addition, there are several production enterprises in China with significant differences in technical levels and environmental awareness. Their attention and investment in environmental protection also differs in the production process. Some enterprises, especially small- and medium-sized enterprises, have a weak sense of environmental protection. Consequently, they cannot proactively collect and treat wastewater. However, owing to personnel, technology, and other reasons, grassroots environmental protection management departments mainly supervise the sewage outlets of enterprises, which makes it challenging to oversee the wastewater treatment process. It is difficult to precisely know the situation of production, collection, and treatment of wastewater in enterprises at the first time, especially the composition of wastewater and toxic substance concentrations, due to a lack of relevant data. It is difficult to quickly and accurately judge the treatment methods and effects of wastewater that has already been produced and may even be misled by enterprises.

5 Countermeasures and suggestions

5.1 Take cleaner production as the core and comprehensively develop whole-process pollution control in industrial water treatment

Unlike developed countries, China is a developing country with a vast territory and large population, and its social and economic construction is accelerating. However, extensive production and management, low resource and energy utilization efficiency, and unsatisfactory pollution discharge exist in some areas. Therefore, given the unbalanced implementation of provisions and the poor stability of wastewater treatment facilities, the phenomenon of excessive industrial water pollution, generally exists. Aiming at the basic contradiction between China's economic development, resources, and the environment, we must take ecological law as a guide. Focusing on the ecological transformation of industrial structure, this study closely combines the basic characteristics of China's social and economic development stage and the construction needs of new industrialization. Taking clean production and circular economy as the core and linking management technology engineering to develop industrial wastewater treatment, energy savings, consumption reduction, and pollution control can be extended to source control. The entire process of pollution control can be realized by integrating pollution prevention from the source and process to the terminal. Only by organically coordinating pollution control with production technology and

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bringing pollution control costs into the production costs of enterprises can we fundamentally solve the problem of the high cost of pollution control.

5.2 Optimize and adjust drainage indicators and promote information disclosure

5.2.1 Introduce the comprehensive toxicity index and optimize the selection of pollutant index.

In the pharmaceutical industry of China, the toxicity index, namely acute toxicity ($HgCl_2$ toxic equivalent meter), was introduced in six series of discharge standards (GB 21903 – GB 21908) [19]. However, there was no reference limiting value, and it was not representative. The comprehensive toxicity method of wastewater is one of the official methods to determine emission limits based on the water quality of the environment in the United States [20,21]. The comprehensive toxicity index is directly used in the discharge standards of water pollutants in many industrial sectors in Germany, is easy to operate and widely representative, and has played a practical role in protecting the water environment quality and preventing environmental risks [20]. Compared to developed countries, the application of comprehensive toxicity indicators in wastewater discharge standards in China is still in its infancy. The comprehensive toxicity index has obvious advantages over other conventional indexes, which could directly reflect the impact of wastewater on the ecosystem when it is challenging to identify water pollutants and lack of emission limits (e.g., wastewater discharge management in industries such as chemicals, pharmaceuticals, and pesticides, which involve the production and use of various chemicals). It is suggested to accelerate the establishment of a comprehensive toxicity index of wastewater and optimize the discharge standard system.

5.2.2 Improve supervision methods and achieve precise control

In order to effectively solve the problems of numerous varieties and the difficulty of supervision of toxic and hazardous pollution of industrial wastewater in China, it is suggested to conduct work from the aspects of comprehensive toxicity management of industrial drainage and classified supervision of tailwater. First, to accelerate the formulation of national and local drainage toxicity standards, specific pollutant indicators should be replaced with comprehensive toxicity indicators, and the problem of difficult monitoring of low-concentration characteristic pollutants in external drainage should be solved. Second, progress in toxic pollutant control technology should be promoted through comprehensive toxicity standards. Finally, given the significant differences in the concentrations, types, and toxicity of tailwater pollutants at different outlets (enterprises and parks), different supervision methods were adopted. For example, enterprises that adopt indirect discharge standards prioritize the monitoring of characteristic pollutants and their concentrations and increase the monitoring frequency. Enterprises that adopt direct discharge standards should focus on comprehensive toxicity and appropriately reduce the monitoring frequency based on stable up-to-standard discharge.

5.2.3 Support basic capacity building and promote information disclosure

First, it is necessary to support basic capacity building, provide technical training for grassroots environmental management personnel, supplement monitoring equipment, and enhance environmental supervision. Second, the education of enterprises should be strengthened to actively protect the environment and abide by the law, and the responsibility consciousness of enterprises to take the initiative to control pollution should be further improved. Finally, it will strengthen the real-time disclosure of environmental pollution discharge information, strengthen environmental and social supervision of key enterprises, and promote pollution reduction and industrial restructuring.

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