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Comprehensive Evaluation on China's Law on Water Pollution Prevention and Control

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Abstract: The newly revised *Law of the People's Republic of China on Prevention and Control of Water Pollution* is crucial for pollution prevention and control in China. In this study, we first review eight aspects of the achievements of the law since its implementation on January 1, 2018. Subsequently, we analyze the issues in implementing the law from four perspectives: (1) the water environment management system and mechanism, (2) supervision of water pollution law enforcement, (3) drinking water source protection and groundwater pollution prevention, and (4) water pollution prevention and control. Accordingly, four countermeasures are proposed from the aspects of the management system, law enforcement capabilities, water source protection, and pollution prevention. Specifically, efforts should be put into coordinated watershed management, river chief system perfection, and water quality improvement, thus promoting the up-to-standard discharge of industrial wastewater, pollutant interception and treatment of municipal pipe networks, recycling of municipal activated sludge, low-carbon and economical treatment of rural sewage, and prevention of rural non-point source pollution.
Keywords: water pollution prevention and control; river chief system; environmental management; environmental standards; water

1 Introduction

Improving water quality via water pollution prevention and control is not only an important aspect of meeting the needs of the growing life quality of people in China, but is also critical to achieve the goals of "ecological civilization" presented by Xi Jinping and the sustainable development 2030 agenda set by the United Nations [1–3]. To fight water pollution, the National People's Congress amended the *Water Pollution Prevention and Control Law of the People's Republic of China* (hereinafter referred to as the WPPC Law) in 2017 and implemented it in January 1, 2018 [4].

To promote the implementation of the WPPC Law for the improvement of the quality of the water environment via pollution prevention and control, the NPC Standing Committee particularly inspected the enforcement of the WPPC Law in the first half of 2019. To obtain technical support and professional reference for this inspection, the NPC Standing Committee invited the Chinese Academy of Engineering (CAE) as a third party to systematically evaluate the implementation of the WPPC Law and the work of various regions and departments. According to the requirements, the key components of the evaluation include the implementation of legal responsibilities, penalties for violations, the main problems in the implementation of the WPPC Law, and suggestions for its improvement.

A consulting project called Evaluation of the Implementation of Law on Water Pollution Prevention and Control was launched by CAE specifically for this evaluation. The specific work was designed and carried out based on reports from the ministries and commissions directly under the State Council and provinces (autonomous regions

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and municipalities) and the research conducted by the evaluation team. The objectives and problems identified during the implementation of the WPPC Law and other related laws were used as orientations for this evaluation. A case study and real-world data were used as the justification for specific reasonings throughout the analysis for possible solutions, aiming to provide technical support and professional reference for National People's Congress's law enforcement supervision of the WPPC Law.

Based on the comprehensive research results of this project, this paper analyzes the achievements and existing problems of the newly amended WPPC Law since its implementation and proposes systematic countermeasures for China's water pollution prevention and control, which will serve as a reference for better implementation of the WPPC Law in the future and to continuously fight against pollution to a greater extent.

2 Implementation and achievements of the WPPC Law

The newly amended WPPC Law contains 108 amendments, including seven chapters and 101 articles, in addition to the Supplementary Provisions. The main contents include the General Provisions, Standards and Planning, Supervision and Administration, Measures for the Prevention and Control of Water Pollution, Protection of Drinking Water Sources and Other Special Waters, and Management of Water Pollution Accidents and Legal Liability. Compared with the 2008 version, the amended WPPC Law added 18 new articles, revised 31 articles, reserved 54 original articles, and repealed 7 articles [4].

Since the implementation of the WPPC Law, related government agents, such as the Ministry of Ecology and Environment and other departments, have strictly formulated standards for the prevention and control of water pollution, revised legal liability, improved the water environmental management system, and strengthened the construction of management ability. Provinces (autonomous regions and municipalities) and governments at all levels have vigorously promoted water pollution prevention and control in industrial, urban, and rural areas, enhanced the protection of drinking water sources, and built groundwater monitoring systems. The water environment quality within these jurisdictions has gradually improved, and the compliance ratio of drinking water with regulated standards has steadily increased. Enforcement was implemented to ensure the implementation of the *Water Environment Law*. Overall, notable progress has been made in the following eight aspects.

2.1 The Great Protection of the Yangtze River has progressed smoothly

Ecological environmental conservation and restoration have been included in the WPPC Law. Government agents, including the Ministry of Ecology and Environment, environmental departments of provincial (autonomous regional and municipal) governments, and other related departments, need to specify the requirements for the protection of the watershed environment to preserve ecological functionalities.

At the end of 2018, the *Action Plan for the Conservation and Restoration of the Yangtze River* was issued to coordinate over 30 departments, including China Three Gorges Corporation, for joint actions to eliminate the sewage outlets and the below-Class-V water bodies around the Yangtze River. In 2018, the Ministry of Ecology and Environment inspected drinking water sources in county-level cities in 11 provinces (municipalities) along the Yangtze River Economic Belt. These efforts promoted chemical pollution prevention and control, remediation of important shorelines from industrial ports and terminals, and ecological protection and restoration in the 11 provinces (municipalities), and the remediation project of 1361 illegal ports along the Yangtze River has been completed.

2.2 The water environmental management system has been gradually improved

Timely objective achievements and joint coordination of environmental protection of key waterbodies have been added to the WPPC Law, enhancing the management of sewage discharge licenses and clarifying the liability and share policies of monitoring data. The responsibilities of water environment management for the Ministry of Ecology and Environment have been enhanced by the coordination of land, water resources, agriculture, and other departments for pollution protection and control. The mechanism of inter-provincial and intra-provincial coordinated watershed management has been steadily reformed via the establishment of ecological environmental supervision in all seven major watersheds, led by the Ministry of Ecology and Environment.

Pollutant discharge licenses are being issued to relevant industries in all provinces (autonomous regions and municipalities) in China. Sewage treatment plants in the built-up areas of 36 key cities were licensed in 2019. By the end of 2018, 39 800 pollutant discharge licenses had been issued for 24 industries nationwide.

Various standards for water pollution prevention and control have gradually been developed and adjusted in China. At the national level, water environment quality standards are designed for three main water types (surface water,

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groundwater, and sea water), including specific limits for 64 water pollutants. Twenty-five province governments have further developed 85 standards for water pollution discharge at the local level that have played an important role in the prevention and control of water pollution. In addition, 343 projects were designed and implemented to improve the water environment for compliance with standards at different geographical levels with different prescribed time periods.

Informatization systems have been developed and embedded in the management and supervision of water pollution protection and control. The main pollution sources in the country have been monitored via the Internet. More than 20 000 enterprises are included in this management platform. In addition, 1881 water quality monitoring stations were built to automatically collect high-quality water quality information at the national level.

2.3 Notable achievements have been made in industrial water pollution prevention and control

The WPPC Law strictly prohibits the dilution of poisonous and hazardous industrial wastewater. Centralized sewage treatment facilities equipped with online monitoring systems must be built at industrial clusters to ensure the reliability of wastewater treatment mechanisms and the compliance of the water quality of treated water with discharge standards.

A list of 10 (categories of) poisonous and hazardous water pollutants (the first batch) was provided by the Ministry of Ecology and Environment and other ministries. Centralized wastewater treatment facilities in industrial clusters have developed rapidly. By the end of 2018, over 97% of 2411 industrial clusters had built facilities for centralized wastewater treatment, coupled with monitoring systems. Many small enterprises with severe pollution problems were closed or relocated nationwide in 2018. The Ministry of Industry and Information Technology and other ministries have improved the standards of clean production to improve efficiency in industries that require large water consumption. For example, the water consumption per ton of steel production dropped by an extra 15.4% from 2016 to 2018, after a previous 19.0% drop led by the 12th Five-Year Plan.

2.4 Achievements have been made in the urban black-odorous water body treatment

To eliminate black-odorous water bodies, the disposal of sludge produced by urban sewage treatment facilities has been defined as an emphasis on new amendments to the WPPC Law. The wastewater treatment fee paid by water users includes the sludge disposal fee for treatment facilities.

With 4332 sewage treatment plants being built in cities (including counties) nationwide by 2018, the daily wastewater treatment capacity has improved to 1.95×10^8 m^3. By 2018, 1009 (95%) of the total 1062 black-odorous water bodies identified in 36 main cities nationwide had been eliminated. In 2019, the *Three-Year Action Plan for Quality and Efficiency Improvement of Municipal Wastewater Treatment (2019–2021)* was jointly issued by the Ministry of Housing and Urban-Rural Development, Ministry of Ecology and Environment, and National Development and Reform Commission. In the plan, the capacity for residential wastewater collection in urban areas should be improved significantly, and black and odorous water bodies should be almost eliminated in three years. Standards have been developed by the National Development and Reform Commission to dynamically adjust wastewater treatment fees to sustain the mechanism of collection and treatment.

2.5 Comprehensive treatment of rural water environment has started

The WPPC Law also supports the construction of wastewater and garbage treatment facilities in rural areas. Adjustments must be made for the comprehensive utilization of livestock and poultry manure and the application of fertilizers and pesticides to meet the requirements for environmental protection. The overdose of fertilizers and pesticides is prohibited to avoid irrigation water pollution.

In 2018, the Ministry of Ecology and Environment and Ministry of Agriculture and Rural Affairs issued the *Action Plan for Tough Battle against Rural and Agricultural Pollution*, followed by a series of component plans designed by the Ministry of Ecology and Environment, Ministry of Housing and Urban-Rural Development, Ministry of Agriculture and Rural Affairs, and Ministry of Finance. Remarkable progress has been made in garbage collection and disposal, wastewater treatment, and toilet retrofitting in rural areas in all provinces and cities nationwide, in which Zhejiang Province has the highest ratio of wastewater treatment. Local action plans for zero pesticide growth have been developed in all provinces, leading to a decrease in the use of fertilizers and pesticides nationwide. In 2018, 70% of livestock and poultry manure from industrial ranches was comprehensively utilized, increasing by 10 percentage points from 2017.

2.6 Drinking water source protection has been strengthened

The WPPC Law emphasizes the security of drinking water and requires investigation and appraisal of the risk of pollution in drinkable water sources. Cities with solo drinking water sources should build extra sources for emergencies or backups. Additional efforts may include coordinating regional networks of water supply, monitoring the water quality of both inlets and outlets, and clarifying the responsibility and emergency management of drinking water security.

The *Guidelines for Emergency Response Plans for Environmental Emergencies in Centralized Surface Drinking Water Sources (for Trial Implementation)* was issued by the Ministry of Ecology and Environment in 2018 to carry out special law enforcement to protect the environment around drinking water sources. The compliance rate of water source quality with related standards in cities at the prefecture level and above nationwide has increased by approximately 2 percentage points since 2017. The drinking water quality monitoring platform built by the National Health Commission covers 90% of prefecture-level cities and counties (districts) nationwide. Response management of urban drinking water emergencies has been built and strengthened by the Ministry of Housing and Urban-Rural Development. Eight national emergency water supply centers were built. The water quality compliance rate of water supply plants in cities increased from 58.2% in 2009 to approximately 96% at present.

2.7 Groundwater pollution prevention and control has gained attention

To prevent groundwater pollution, the WPPC Law states that abandoned mines, drilling wells, water intake wells, etc., shall be capped or refilled, and specific industrial areas should take proper actions to avoid pollution leakage into groundwater.

In 2018, the Ministry of Ecology and Environment listed about 120 000 "Dual Sources" of groundwater pollution. Insulation retrofitting has started and been moving forward for key groundwater pollution sources, such as gas stations, the completion ratio of which has reached over 70% of the gas stations in 15 provinces (municipalities). The National Groundwater Monitoring Platform was built in 2018, with 20 466 monitoring sites covering 31 provinces (autonomous regions and cities) covering around 3.5×10^6 km^2. The *Implementation Plan for Groundwater Pollution Prevention and Control* jointly issued by the Ministry of Ecology and Environment, Ministry of Natural Resources, and five other ministries in 2019 further clarified the plan for groundwater pollution prevention and control.

2.8 Water environment law enforcement has been significantly strengthened

Recently, the WPPC Law introduced daily fines for water pollution cases, which are complementary to the *Environmental Protection Law*. The amendments strengthened the law enforcement powers of the supervision and administration agents to ensure effective implementation of the law.

Environmental violations related to water increased significantly in 2018. Over 20 000 cases were panelized, with a total fine of over 3 billion CNY. Over 180 cases fined on a daily basis were disclosed in Tianjin, Zhejiang, Fujian, Shandong, Guangdong, Hainan, Ningxia Hui Autonomous Region, Xinjiang Uygur Autonomous Region, and other provinces, leveraging the costs of environmental violations. The Supreme People's Court and the Supreme People's Procuratorate issued the *Interpretation of the Supreme People's Court and the Supreme People's Procuratorate on Several Issues Concerning the Application of Law in Handling Criminal Cases of Environmental Pollution*, which serves as strong legal support to fight water pollution crimes. In 2018, 62 criminal cases related to environmental resources were identified nationwide, reflecting an annual increase of 12.9%. Simultaneously, 314 civil cases related to environmental resources were concluded nationwide, an increase of 30.3% from the previous year. The accountability of personnel of relevant administrative authorities for their failure to perform their duties has been strengthened. By the end of 2018, nearly 6000 local people had been talked to by the administration, and over 8000 held accountable.

3 Issues in the implementation of the WPPC Law

Four issues exist in water pollution prevention and control: the mechanism of water environment management, law enforcement and supervision of water pollution, drinking water source protection and groundwater pollution prevention, and the general prevention and control of water pollution.

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3.1 Issues of the mechanism of water environment management

3.1.1 Expanding education regarding the WPPC Law

In some areas, governments still prioritize economic development over environmental protection. Education of the public under WPPC Law is still inadequate. Although aware of this, the general public does not have the right atmosphere of learning or legal knowledge to obtain a deeper understanding.

3.1.2 Overall management of watersheds needs to be strengthened

The 28th clause, which was newly added to the amendment of the WPPC Law, stipulates a coordinated mechanism for protecting the water environment across watersheds. However, the existing management cannot realize this mechanism because: (1) There is no information sharing in existing monitoring networks, (2) eco-compensation still relies on negotiations between governments, and (3) pollution accidents are mostly handled by local governments. A coordination mechanism across the administrative boundaries of land, sea, and watersheds has not been established. Additionally, due to the lack of coordination of environmental protection laws for surface water and ocean, land-based pollution discharges have led to increased water eutrophication nearshore.

3.1.3 The implementation of the river chief system needs to be strengthened

The 5th clause of the amendment of the WPPC Law requires the establishment of a river chief system and its responsibility for water environment protection. Preliminary planning and patrols made by some river chiefs do not have adequate power to solve critical environmental issues such as landfilling along rivers and lakes, aquaculture development, illegal construction, garbage littering, and illegal sand mining. In addition, untreated wastewater discharge from industrial, residential, and rural areas is also serious. Systematic design of coordinated wastewater collection infrastructures and treatment facilities considering water quality is lacking in river and lake pollution control. The overall improvement in water quality in rivers and lakes is not obvious, with repeated pollution in some cities.

3.1.4 The water pollution prevention and control standards system needs to be revised

The 17th clause of the WPPC Law stipulates that compliance deadlines should be determined based on the local objectives of improving the water environment quality. The current *Environmental Quality Standards for Surface Water* adopted a uniform standard that can hardly adapt to the spatial variances across watersheds, causing issues of over-protection and protection in different regions. Indicators for controlling poisonous and hazardous water pollutants are not comprehensive enough to attract sufficient attention for aquatic ecology protection and to prevent potential water quality risks. Cross-referencing should be adopted when selecting relevant indicators (e.g., nitrogen-related indicators) and determining their thresholds in discharge based on the *Sea Water Quality Standard*. Further adjustments are needed to determine the discharge standards for pesticides and heavy metal pollutants such as thallium.

3.1.5 The pollutant discharge license management system needs to be improved

The 21st clause of the WPPC stipulates that the type, concentration, total volume, and receiving water body should be clearly specified when issuing a pollutant discharge license. As pollution discharge license management has just begun and the corresponding supervision system is still under development, problems may still exist. For example, continuous online monitoring of industrial pollution sources is not applicable to environmental protection agent, and water sampling at mid- or small-sized enterprises is inefficient and not timely. Efficient coordination of the pollutant discharge license management system with other management systems, such as environmental impact assessment, environmental tax, environmental monitoring, and environmental statistics, should be built. The correlation between pollution discharge licenses and the tolerance capacity of the corresponding watersheds needs to be quantified so that the pollution discharge license system can efficiently support the objectives of water quality management of single or multiple watersheds.

3.1.6 The emergency management capacity needs to be strengthened

The 77th clause of the WPPC Law stipulates that enterprises and public institutions with potential risks of water pollution accidents should develop emergency plans and rehearsals on a regular basis. At present, the long-term employment of professional experts, precise emergency plans, and prompt responses are needed in some enterprises and public institutions with high water pollution risks. Owing to the lack of professional teams to handle water pollution emergencies, gathering resources from other loads for post-emergency management is a common strategy for local governments. Without a joint prevention and control mechanism in key watersheds such as the Yangtze

River, multiple administrative regions could be impacted in the case of a water pollution accident in one or multiple enterprises among the large number of heavy chemical industries and industrial parks in the watershed.

3.2 Issues in water pollution law enforcement supervision

3.2.1 Environmental law enforcement ability is insufficient

The enforcement power of the supervision and administration departments for the prevention and control of water pollution has been enhanced by the WPPC Law to ensure its implementation. However, the imbalance between the capability and management of local governments with the requirements of the law impairs the efficiency of the WPPC Law's implementation and supervision. The establishment of a regulated mechanism for environmental law enforcement requires support from information systems, intelligent systems, and cost-effective strategies. However, online monitoring equipment purchased by governments can only equip selected regions and pollutant discharge units, whereas privately owned equipment is not legally eligible for government law enforcement and supervision. Thus, a supervision network with full engagement from society is yet to be built, and enterprise information disclosure is also important but inadequate.

3.2.2 Vessel sewage is difficult to supervise

The 61st clause of the WPPC Law stipulates that the people's governments are to leverage sources to build infrastructure and facilities for collecting, transmitting, and disposing pollutants and wastes from vessels. Such pollution sources are too mobile to be efficiently supervised, especially for small vessels and hazardous pollutants, and the corresponding treatment capacities at ports, wharfs, loading stations, and unloading stations are generally insufficient in China. These are the actual installations and operations of wastewater treatment facilities in vessels. This problem is more severe in inland waterways. The construction and operation of cabin washing stations is seriously inadequate and costly. For cabins used for chemical transportation, the volume of water used for washing may vary drastically depending on the type and concentration of chemicals. Cabin washing water may contain a large number of nondegradable poisonous organics, which are difficult to treat in compliance with standards.

3.3 Issues in drinking water source protection and groundwater pollution prevention

3.3.1 Drinking water source protection needs to be strengthened

The 69th clause of the WPPC Law specifies the necessity of investigating and appraising the environmental situation in drinking water resource protection areas, screening the factors for pollution risk, and responding to prevention risks.

Potential risks exist in areas where the quality of drinking water does not comply with the standard. Such problems can be found in 10% of urban water sources in China. Owing to the influence of terrain and geological conditions, there are 21 cities in China with a water source compliance ratio of 0, including 16 groundwater water sources, 3 lake water sources, and 2 river water sources. Among the surface sources of drinking water in cities at the prefecture level and above, inter-connections exist in 180 first-grade water source protection areas and 341 second-grade water source protection areas. Among the cities at the prefecture level and above, 31 cities were supplied by a single water source, without other sources for emergency or backup. To date, no risk evaluation or specific emergency protection projects are required to protect against risks to drinking water sources.

Administration boundaries restrict the comprehensive protection of watersheds from water sources. At present, coordinated management is needed by multiple provinces (10 cities) or multiple municipalities (46 cities). The transboundary drinking water source area is characterized by the fact that the upstream and downstream watersheds belong to different administrative regions. Given that water supply or water source cultivation in the upstream area needs to sacrifice economic development to protect and renovate the water sources, the lack of compensation impairs the motivation to protect the water source.

Owing to issues in the design, construction, operation, and management of secondary water supply facilities, there are potential safety risks for the water quality of secondary water supply in some urban residential areas.

3.3.2 Groundwater pollution prevention capacity is severely inadequate

The 40th and 42nd clauses of the WPPC Law detailed measures to prevent groundwater pollution for specific industrial enterprises, areas, and facilities, which strengthened the prevention and control of groundwater pollution. However, baseline groundwater pollution is still unknown in most regions of China. The facilities to protect groundwater are insufficient because: (1) a list of sensitive groundwater pollution sources and staged prevention and control strategies are lacking in most of the country, and (2) the local governments and enterprises have weak

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awareness of groundwater prevention. The cross-sectoral “Dual Sources” monitoring system and the national groundwater monitoring project are not well integrated. A standardized system and the capacity of groundwater monitoring have yet to be developed for real-time monitoring of key groundwater pollution sources, and there is a lack of collaboration and optimization in cross-regional groundwater environment monitoring networks.

3.4 Issues in the general water pollution prevention and control

3.4.1 Violation of pollutant concentration standards in industrial discharges occurs from time to time

The 45th clause of the WPPC Law emphasizes that industrial wastewater cannot be discharged until it has been pre-treated to meet the requirements of inflow for centralized treatment facilities. Entities operating centralized treatment facilities are responsible for ensuring that their water discharge meet the corresponding standards.

The proportion of heavy industries is high in China’s industrial structure, which leads to a relatively high total amount of industrial pollution discharge that is ununiformly distributed across regions and industrial sectors. Violation of pollution discharge standards is common in certain industries whose wastewater treatment facilities are not stable, especially in developing regions and decentralized industries such as fine chemicals. The instability in the operations of centralized wastewater treatment facilities in industrial parks is mainly due to the discharge of enterprises that violate the inflow requirements of centralized wastewater treatment facilities. The low-cost biochemical treatment processes usually adopted by centralized treatment facilities in industrial clusters are unable to adapt to drastic variations in industrial wastewater in terms of volume, chemical composition, and concentration. Inadequate supervision of an enterprise’s discharge makes it difficult to differentiate the responsibilities between enterprises and centralized treatment facilities when a violation occurs.

3.4.2 Issues in urban sewer network is relatively serious

The 49th clause of the WPPC Law emphasizes the construction of urban sewer networks and stipulates that the administrative department of construction in local governments at or above the county level should organize and build centralized wastewater treatment facilities and the associated sewer networks in accordance with the planning of urban wastewater treatment facilities.

The main issues in urban sewer networks in China are represented by three aspects. First, the collection networks cannot capture all wastewaters because the main networks leveraged too much attention over tributary branches during construction. Thus, a large amount of untreated wastewater is discharged directly into rivers and lakes. According to the pollution loading statistics, the sewage treatment ratio of 31 provinces (autonomous regions and municipalities) and the national average ratio was only 60%. In other words, 40% of the pollution load is discharged directly or indirectly into urban water bodies. Second, sewer systems are overloaded by groundwater and stormwater intruded by damaged pipes or incorrect pipe connections. According to a survey, the proportion of groundwater in sewage is as high as 28–40% in southern China. Stormwater pipes that are incorrectly connected to sewage pipes may deliver an unexpected surplus inflow to wastewater treatment plants in wet weather, which causes overflows exceeding the discharge standards. Third, the combined sewer systems mix sewage with the initial stormwater, which frequently causes overflows and black and odorous water bodies on wet-weather days. The results of an investigation of 23 separate sewer systems in a coastal city in eastern China showed that, on average, 26.2% of the total wastewater in the service areas was illegally discharged into stormwater pipes, with the highest being 70%, severely polluting the initial stormwater. As the city continues to expand, the distance and flow rate of the conveyance in combined sewer systems become long and slow on dry-weather days, favoring the deposition of particulate pollutants. The deposition ratio could exceed 40%, causing pollution with overflow into rivers on wet days [5]. According to a survey, the chemical oxygen demand (COD) of combined sewer system overflows in southern China can be as high as 1200 mg/L with an average of approximately 540 mg/L. Separate sewer networks with many incorrect connections exhibit similar situations [6,7]. Regardless of the type of sewer system, the maximum and median values of concentration are both two times higher than the data reported in developed countries (Germany, France, the United States, etc.) [3].

3.4.3 Municipal sludge disposal is not well standardized

The WPPC Law stipulates that the sludge produced by urban sewage treatment facilities should be treated and disposed of in a safe manner (51st clause), and the corresponding cost should be included in the wastewater treatment fee (49th clause).

Sludge treatment and disposal are critical issues for water pollution control in China. The long-term emphasis on water and neglect of sludge has led to a serious backlog of sludge. By 2017, the statistics of 4119 sewage treatment

plants built and operated in cities and towns nationwide showed that 1.56×10^8 t/d of the 1.82×10^8 t/d sewage treatment capacity had been used, which produces sludge (80% moisture content) of approximately 4×10^7 t/a (calculated according to the sludge with a water content of 80% of 7 t generated per 10 000 t of sewage), averagely 1.1×10^5 t/d. According to the 12th Five-Year Plan, the safe disposal of sludge in China is only 3.74×10^4 t/d (excluding organic towns), which is only 35% of the sludge production. The total investment in the construction of urban sewage treatment and recycling facilities during the 13th Five Year Plan period was about 564.4 billion CNY. Although sewage treatment is still leveraged more than sludge treatment and disposal, 150.6 billion CNY is assigned to new sewage treatment facilities, including 29.4 billion CNY for new or improved sludge safe treatment and disposal facilities [8].

Limited by the quality of sludge in China, reuse technologies and equipment from other counties cannot be adopted by facilities in China, leading to a low overall benefit. The installation ratio of anaerobic sludge digestion in China is less than 5% and is not fully operatable. At present, only 20 of the 60 anaerobic digestion facilities built in China operate in a stable manner. A large amount of sludge cannot be utilized, resulting in a waste of resources and energy [9].

At present, sludge treatment and disposal fees account for only a small fraction of sewage treatment fees in China, with an unclear price mechanism in most provinces and cities.

3.4.4 The treatment capacity of rural wastewater and manure from decentralized livestock and poultry is low

The 53rd clause of the WPPC Law stipulates that the quality and use of fertilizers and pesticides should satisfy the requirements for water environment protection. The 55th and 56th clauses clearly stipulate that the excessive use of fertilizers and pesticides and the pollution of livestock and poultry stools should be controlled to avoid polluting irrigation water.

Rural wastewater treatment technologies must adapt to the local conditions. At present, the 20% treatment ratio of rural wastewater is much lower than that of urban wastewater. However, urban wastewater and industrial wastewater treatment technologies are widely adopted in rural wastewater treatment, which do not recycle nitrogen and phosphorus for agriculture, raising the cost and management complexity of rural wastewater treatment. The tailwater discharges of some facilities in East China were not compliant with the standards because they exceeded total nitrogen (TN) and total phosphorus (TP).

Manure from the decentralized livestock and poultry breeding industry and aquaculture drainage have caused the release of fertilizers and pesticides and serious downstream pollution. Due to the imbalance between the agricultural area and the sizes of livestock and poultry farms, the untreated discharges of manure from the decentralized livestock and poultry industry and the drainage from aquaculture farms aggravate agricultural non-point source pollution. The results of the First National Survey of Pollution Sources Bulletin showed that the discharge (loss) of COD, TN, and TP from agricultural sources were 1.324×10^7 t, 2.7×10^6 t, and 2.8×10^5 t, respectively, of which livestock and poultry breeding accounted for the most. The average fertilizer application in China is 21.9 kg/*mu* (1 *mu* equals to ~0.067 ha), which is higher than the world average of 8 kg/*mu*, 2.6 times that of the United States, and 2.5 times that of the European Union [10]. The seasonal average utilization ratio of chemical fertilizers in China is 30%, which is much lower than the 60%–70% in developed countries such as Europe and the United States, causing severe release of effective chemical components downstream [11]. Simultaneously, the use of pesticides per square meter in China is 2.5 times the world average, with an average utilization ratio of only 35% [10]. Abuse of pesticides and antibiotics is common in small-scale agricultural production.

4 Measures for further implementing the WPPC Law

To further implement the WPPC Law, the prevention and control of industrial water pollution, interception and treatment of urban wastewater in sewer systems, disposal and reuse of municipal activated sludge, low-carbon economic treatment of rural wastewater, and prevention of rural non-point sourced pollution need to be strengthened. To do this, the improvement of water environment quality should be considered as the basis for coordinating management systems, law enforcement, water source protection, and pollution prevention and control (Fig. 1) to guarantee the success of the fight against pollution and build a beautiful China.

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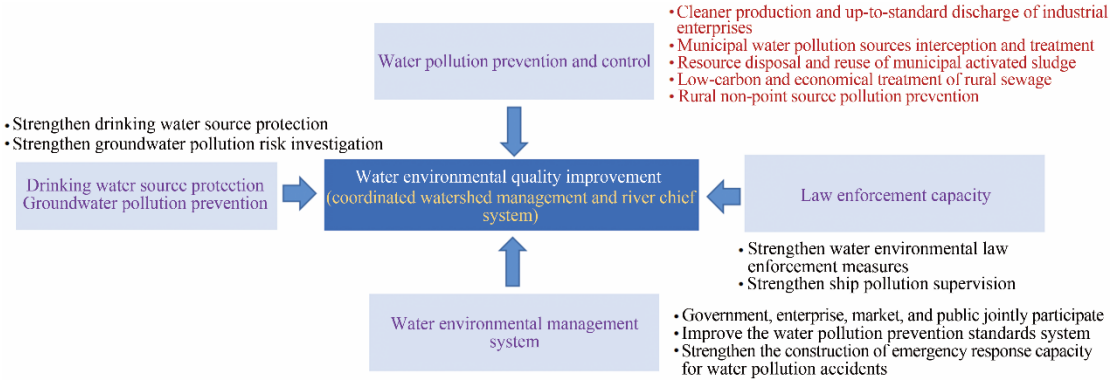

Fig. 1. Overall framework for the implementation of WPPC Law.

4.1 Continuously innovate water environmental management systems and improve the market by diversifying engagements

4.1.1 Improve the water pollution prevention and control mechanism with the engagements of governments, enterprises, market, and the public

Education on the WPPC Law should be promoted among the public, especially leaders at all levels, to raise awareness of legal and scientific water treatment. An atmosphere of learning about the WPPC Law in society needs to be built to engage everyone in water environment protection. The engagement of enterprises, social organizations, the public, and other social forces in this system are critical to building a comprehensive supervision mechanism representing the coordination of government leadership, enterprise operation, market guidance, and public participation. Thus, the success of the battle against pollution and building a moderately prosperous society can be guaranteed in all respects.

The marketization of water pollution treatment needs to be further explored. The public-private partnership mode in the field of environmental protection needs to be strengthened for its standardized and healthy development by improving the objective-oriented charging and return mechanism. Tax and financial policies must support the sustainable development of technology-innovative companies in environmental protection and encourage private enterprises in green industry development. Leading enterprises with a high level of pollution prevention and control should be rewarded by tax reductions and relief. Private enterprises need to be encouraged to combine their advantages in technology, engineering, equipment, and other aspects to complement public enterprises to jointly undertake public-private partnership projects and expanding markets. Green financial policies need to be developed and imported through the marketization of pollution treatment businesses and the establishment of a green price mechanism.

4.1.2 Strengthen the coordinative watershed management

The appointment of river chiefs is important for strengthening coordinated watershed management. The management, protection, and restoration of the water quality and ecological system of an entire watershed should focus on the coordination of water resources, quality, and functionality both upstream and downstream, which is subject to the establishment of a management mechanism for the river chief system that balances the power, duty, and benefit of the river chiefs. Strengthening such coordinated prevention and control of the entire watershed will bring about mutually beneficial circumstances for both protectors and beneficiaries. Such coordination also requires the sharing and publishing of water quality information of both the upstream and downstream, which cannot be realized until the establishment of supervision, administrative, and law enforcement agencies for the watershed ecological environment, an overall coordinated mechanism, an information sharing platform, and an integrated water environment quality monitoring network. The targets of watershed water quality management should be composed of four elements: a pollutant discharge license, cap-on trade, ecological compensation, and territorial responsibility.

An ecological compensation mechanism with clear standards for rewarding and punishing should be built based on watershed section assessments, linking the benefits and responsibilities of environmental protection to simplify ecological compensation. By balancing power responsibilities and reasonable compensation, the governments of both upstream and downstream areas of a watershed should negotiate to coordinate compensation, counterpart cooperation, industry relocation, talent training, and joint construction of parks. Building a trading platform between upstream and downstream for pollution credits and water credits should be encouraged, which will help establish an

assessment mechanism for ecological compensation in a watershed and allow intra-provincial pollution load trading. The responsibilities and efforts taken by the upstream parties of a watershed could be compensated economically by the downstream parties for the associated improvements in the ecological environment.

The comprehensive prevention and control of water pollution accidents in key river basins, such as the Yangtze River, need to be enhanced. It is necessary to: (1) clarify the responsibilities of the coordination agent of the river basin in handling water pollution accidents, (2) establish a prevention and early warning mechanism, and (3) build a professional emergency response team for water pollution accidents. Proper prevention of water pollution and an emergency response plan need to be developed for key river basins such as the Yangtze River. In the case of an emergency, these clarified responsibilities, established warning mechanisms, and the professional team will properly and effectively handle all situations during and after an accident.

4.1.3 Perfect the assessment mechanism of river chiefs

The assessment of the river chief should be based not only on the river chief's inspection and patrol of rivers (lakes) but also on the improvement of water quality and pollution control. By including comprehensive water quality improvement and pollution loading interception ratios in assessment standards, river chiefs will be pushed to effectively apply the corresponding investments and resources to control river and lake pollution, improve water quality, leverage sewage treatment plant quality and efficiency, and retrofit sewer networks.

4.1.4 Perfect the standards system of water pollution prevention

The variation across different watersheds or regions and coordinated intra-watershed management should be represented in the determination of the standards of surface water quality as the baseline of the water environment, embodying the development theory of "prioritizing ecological protection and promoting green development." The implementation of national watershed standards should be processed by emphasizing the drafting of watershed discharge standards, which should be the basis for building and adjusting local wastewater discharge standards to further object-oriented water environment quality management. The operability of the transition between the old and new standards of environmental quality should be considered during its drafting to ensure smooth environmental management.

4.1.5 Strengthen the construction of emergency response capability for water pollution accidents

The early warning and prediction of water pollution accidents should be enhanced by both advanced technologies and a well-educated workforce, so that a smart decision-making support system for urban water environment pollution emergency management can be established.

A professional team for water environment emergencies should be built by regularly training the responsible employees in enterprises and institutions. Enterprises and institutions with high water pollution risks should have a comprehensive safety management system involving skill training for staff and a daily management protocol to respond to water pollution emergencies.

A response mechanism is critical for water pollution emergencies. The development of this mechanism should consider its effectiveness and operability, emphasizing the features of precision, science, timeliness, and adaptability so that the mechanism can be dynamically managed and progressively improved over the long term. The emergency plan should be drilled for the entire process to expose and address problems, improving the effectiveness of the plan in a timely fashion.

4.2 Further strengthen the construction of law enforcement ability and improve the effectiveness of supervision

4.2.1 Strengthen the law enforcement means for water environment

Law enforcement means should be comprehensively applied to implement a dual punishment system for the main persons responsible for pollutant discharge. The dual punishment system states that the punishment should not only apply to illegal entities, but also to persons who are mainly responsible, directly responsible, or responsible in other ways according to laws, so as to leverage the attention of the responsible person of an enterprise to comply with the corresponding standards. The accuracy of environmental supervision and law enforcement should be improved by taking full advantage of science and technology, such as online monitoring, satellite remote sensing, and unmanned aerial vehicles, to fully embody the effect of the improved efficiency of law enforcement by big data, artificial intelligence, and other technologies. Supervision should also be improved by increasing the size of the frontline environmental law enforcement team, equipment, and capital investment.

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The efficiency of the enforcement of the *Water Environment Law* needs to be improved by simplifying the corresponding procedures. Water environment violations mostly comprise illegal discharges and leaky discharges, which are extremely difficult to justify legally with evidence in complex river networks. For example, illegal discharge can be determined when the volume of water discharged into sewage treatment plants or their own sewage treatment facilities is significantly lower than the volume of industrial and domestic sewage. If the water quality at the plant outlet exceeds the standard, the plant owner should be punished. The lack of an environmental law enforcement force and the problem of sampling could be solved by enabling online monitoring data to be used as evidence of water environment violations.

4.2.2 Strengthen vessel pollution supervision

Joint supervision and law enforcement collaborated by multiple departments need to be strengthened by focusing on the supervision of the water for ballasting water sterilization, cabin washing water for hazardous chemicals, and tracking of all processes for vessels with hazardous chemicals. The research and development of core technologies and equipment for responding to vessel pollution emergencies should be enhanced by leveraging the construction of on-ship wastewater treatment equipment and the treatment capacity of shore-based wastewater facilities. Specifically, efforts need to be made to (1) develop rapid, efficient, and environment-friendly technologies for vessel wastewater treatment and corresponding equipment, and (2) leverage the on-ship collection system of garbage and wastewater. The service functionality of cabin washing stations and the establishment of cabin washing operation standards for vessels with hazardous chemicals are subject to (1) surveying the operation situation of existing cabin washing stations in key shipping channels, such as the Yangtze River, (2) encouraging investment by the capital market, and (3) distributing cabin washing stations reasonably and strategically. Low-consumption, fast, efficient, and green treatment technologies and core equipment should be developed for treating chemical tank washing water.

4.3 Continuously strengthen the source protection of drinking water supply and promote the prevention and treatment of groundwater pollution

4.3.1 Strengthen the protection of drinking water supply sources

The implementation of the *Guide for Compiling Risk Sources Directory of Drinking Water Sources* is recommended to improve the scientific character and effectiveness of risk management. The prevention and control of emergencies connected with waterbodies should be strengthened by (1) building a three-level responding system connecting risk sources, related water bodies, and water intake, and (2) planning and distributing key prevention and control projects at all levels. It is also important to improve emergency facilities for pollutant interception, directing, collection, and disposal to strengthen the construction of emergency water sources or realize a networked water supply.

Microscale organic pollutants must be screened for priority. Efforts need to be made at the national level in accordance with international analysis methods for water quality of compound pollution and overall health effect evaluation. To develop environmentally friendly technologies for improving drinking water quality, microscale organic pollutants in various watersheds in China, such as the Yangtze River, should be screened to rank their priorities, and their discharge limits should be determined for coordinated revision of the *Environmental Quality Standards for Surface Water* and *Standards for Drinking Water Quality*.

The management of secondary water supply should be innovated to promote the transformation of secondary water supply facilities. Government and administration agents for different industries may lead and organize various relevant departments, water supply enterprises, and interest-related communities to jointly participate in retrofitting. Funds should be raised from multiple sources, considering the financial status of local governments, affordability of water supply enterprises, and acceptance of beneficiary users. Governments in different locations should adopt a management mode suitable for local features according to relevant national and local laws, standards, and local realities. The safety of the water supply for urban residential communities should be ensured by localized management modes for secondary water supply facilities with clear rights and responsibilities, professional management, and adequate supervision.

The safety of the rural drinking water supply should be improved. Given the extreme diversity of sources of rural water supply in China, countermeasures may vary drastically. In remote parts of northwestern China, the quantification of water supply is limited, which can be solved by increasing counterpart assistance, promoting the construction of mother and small reservoirs, reusing of reclaimed water, and water-saving cities. However, in southern China, water quality is the sensitive limit for drinking water supply, which can be easily affected by rural residential wastewater and pollution discharges from agricultural farming and ranching. It is suggested that the

protection of drinking water sources should be improved through comprehensive improvement of the rural environment.

4.3.2 Conduct groundwater pollution risk investigation and formulate technical guidelines and standards

The protection and control of groundwater pollution should be managed using a three-tier structure: (1) restoring and treating sites with severe risk sources, (2) monitoring sites with medium risk sources for early warning, and (3) supervising and managing sites with minor risk sources. The hierarchical structure of sites must be determined and listed with priority by surveying and screening the risks of groundwater pollution in key areas. Specifically, the baseline and original values of groundwater need to be determined; the sources and problems associated with groundwater pollutions should be identified in key areas (such as the Beijing–Tianjin–Hebei region and Xiong'an New Area); and the plans for area-wide prevention and control of groundwater pollution should be devised in a problem-oriented way.

A three-tier groundwater environment monitoring network needs to be established covering the levels of nation, province, and "Dual Sources." A coordinated supervision system that includes multiple factors from the surface water, soil, and groundwater should be realized by establishing a regular inspection and coordinated early warning mechanism for pollution risks. Assessments of suitability and risk should be conducted systematically for groundwater recharge areas by (1) accurately gauging the inter-correlations among mountains, waters, forests, farmland, lakes, and grassland within the ecosystem; (2) considering the adjustment of water sources, the restoration of aqua-ecological systems, and ecological needs in a coordinated fashion; and (3) performing long-term monitoring and engineering system optimization.

4.4 Deeply promote the prevention and control of water pollution, and enhance the legal and scientific water treatment

4.4.1 Promote environment-friendly production of industrial enterprises and clarify the responsibilities for compliance of discharges with corresponding standards

Source control, mitigation in production, and end-point risk elimination are critical for a highly efficient life cycle for the prevention and control of industrial wastewater pollution. Retrofitting the traditional manufacturing process into such an environmentally friendly system should be coordinated by management, technology, and engineering. Pilot projects of industrial ecology can be conducted at typical enterprises and a number of industrial parks through the integration of mass, energy, and information to form the industrial metabolism and symbiosis of a circular economy mode with Chinese characteristics.

To clarify the responsibilities for compliance with discharge standards, local environmental protection departments should strengthen the supervision of industrial enterprises to ensure (1) the suitability of treatment processes of wastewater treatment plants to the characteristics of industrial wastewater in the service area and (2) the implementation of the required pre-discharge treatments. The responsibilities of industrial enterprises and wastewater treatment plants should be clearly differentiated by justifying the source of the problem: either the pre-discharge treatments (industrial enterprises' responsibility), wastewater treatment processes (wastewater treatment plants' responsibility), or both. Governments should strictly supervise the treatment processes and requirements according to the specifications of the entrusted contracts and relevant national standards. The discharge standards need to be optimized by adding comprehensive toxicity indicators for those being drained directly into the water environment and prioritizing the monitoring and control of pollutant concentrations at the outlets of enterprises that discharge indirectly.

4.4.2 Strengthen the interception and treatment of sewage in urban sewer networks

The retrofitting, repair, and improvement of urban sewer networks must be accelerated with the implementation of non-digging diagnosis and repair of sewer problems. Optimized management and operation technologies should be vigorously implemented, including the prevention of dry-season sedimentation, mechanical dredging, and automatic hydraulic flushing. Traditional sewer facilities need to be integrated with sponge cities by strengthening operation management to raise the sewer overflow threshold and reduce sewage discharge on wet-weather days. The development of infrastructure construction and the environmental protection market needs to be promoted by improving the investment and financing mechanisms for urban sewer network construction.

4.4.3 Improve the sludge disposal and reuse management system

A cross-functional coordination mechanism should be established for sludge disposal to pave the way for resource utilization and promote sludge reduction, stabilization, harmlessness, and resource utilization. The joint treatment of

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sludge and various organic wastes needs to be developed as a technical route to treat waste into resources and energy. A suitable technical route for sludge disposal and reuse in China can be determined based on the two major approaches of landfilling and producing building materials.

4.4.4 Vigorously promote the "low-carbon, economical, simple, and convenient" mode of rural wastewater treatment

In the next 20 to 30 years, rural wastewater treatment will constitute a major portion of China's wastewater treatment market. Since the differences in the environment across different regions are drastic, all provinces (autonomous regions and municipalities) should formulate their water pollutant discharge standards for rural wastewater treatment facilities according to the adaptation by local communities. Treatment technologies for urban sewage or industrial wastewater are generally not recommended in most rural areas unless specifically required. To promote the sound development of rural water pollution prevention, it is important to (1) establish a market and operational mechanism for rural wastewater treatment, (2) entrust a third-party professional institution to operate rural wastewater decentralized treatment facilities, and (3) maintain the normal operation of rural wastewater treatment systems.

4.4.5 Vigorously promote the prevention and control of agricultural non-point source pollution with circular agriculture combining planting and breeding

Based on the supply and demand balance between the size of farming areas and the number of livestock and poultry, environmentally friendly treatment of livestock and poultry manure could be established to serve a circular agriculture economy. Collecting sewage and manure from decentralized ranches for centralized treatment, supporting large-scale ranches, and maintaining centralized livestock and poultry manure collection sites will help establish a ranch environment management system based on the reuse of manure and regional environmental quality objectives.

A project for the comprehensive prevention and control of local farmland non-point-source pollution should be constructed through adaptation to local conditions. The efficiency of fertilizer use should be leveraged by (1) promoting the use of organic fertilizers, and (2) maintaining the expansion of soil testing and customized fertilizer application to major crops. Different management strategies should be applied to rural runoff, including (1) building facilities for runoff interception and reuse in farmlands with slopes between 5° and 25° and (2) building ecological ditches and multi-pond systems in plains areas with a slope below 5°. Simultaneously, the slow-release effect and utilization efficiency of fertilizers should be promoted by developing new fertilizers, such as slow-release fertilizers, controlled-release fertilizers, commercial organic fertilizers, and biological fertilizers.

Supervision and management of the abuse of pesticides and antibiotics should be strengthened. At present, there is no supervision over the management of pesticide and antibiotic use in the agricultural production of small-scale businesses. The flow and use of pesticides should be included in the electronic supervision system to promote the use of efficient, low-toxicity, and low-residual pesticides. Although the promotion of agricultural technology professionals is critical to agricultural non-point-source pollution control, profit orientation means, such as helping market green agricultural products, would be advantageous. However, it is also important to encourage farmers to participate in water pollution prevention and control measures by financially supporting their efforts and contributions in producing green agricultural products.

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