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Strategy for Assuring Water Security in the Haihe River Basin by 2035

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Abstract: Water security in the Haihe River Basin is an important component of China's ecological civilization, and it is vital for high-quality national development. Considering the development requirements to achieve this security, here, problems regarding water security assurance from the perspectives of water resources, water environment, water ecology, and flood disasters were analyzed. Subsequently, the development trend of water security in the Haihe River Basin by 2035 was predicted through data simulation. On this basis, assuring water security in the Haihe River Basin by reinforcing measures for protecting water ecology and highlighting the role of water resource carrying capacity were proposed. Focus should be placed on developing capacities regarding (1) systematic allocation and efficient utilization of water resources, (2) comprehensive improvement in the water environment, (3) governance and restoration of basin ecology, and (4) prevention of and emergency response to flood disasters. Furthermore, the following proposals were made from a technological perspective: (1) implementing new strategies for the conservation and efficient utilization of water resources, (2) ensuring drinking water safety and improving water governance capacities, (3) establishing a water ecological pattern that features human–water harmony, and (4) developing a flood disaster prediction and response mechanism.
Keywords: Haihe River Basin; water security; water resource; water environment; water ecology; flood disaster

1 Introduction

Ensuring water security is a key part of ecological civilization construction in China, which supports the goal of a Beautiful China by 2035 and ensures that ecological environment quality improves fundamentally. As one of the seven major river systems in China, the Haihe River Basin plays an important role in the economic and social development of the country [1]. During the 13th Five-Year Plan period, achievements were made in the Haihe River Basin as part of the South-to-North Water Diversion Project, including improvements in water pollution control, groundwater overexploitation regulation, and wetland protection. The water environment in the basin has improved significantly. In the Haihe River Basin, the double water source supply system, including the middle route of the South-to-North Water Diversion Project and the Luan River Water Diversion Project, has been further improved. The upstream and downstream horizontal ecological compensation mechanism for the Luan River diversion into Tianjin has been established; unconventional water has become an effective supplementary water source, and the utilization rate of recycled water and desalinated seawater has been steadily improved. The water quality and quantity of urban sewage treatment have been improved. Urban sewage treatment facilities are almost

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universal in the main cities in the region. The water quality index of the effluent from the sewage treatment plants has met the Class IV standard for surface water, and the harmless disposal rate of sludge has reached 95%. The quality of the water ecological environment has been significantly improved. As for rivers entering the sea, the pollution control strategy of "one river, one policy" has been implemented. The inferior V waterbodies of rivers entering the sea have been almost eliminated. The capacity for flood control and drainage has increased continuously. The reinforcement project for dangerous large- and medium-sized sluices has almost been completed.

To achieve the water treatment goal for the 14th Five-Year Plan period (there are rivers, water, fish, and grass, and harmonious coexistence is realized between man and water) [2], the systematic governance of mountains, water, forests, fields, lakes, and grass will continue to be carried out; pollution will be controlled accurately, scientifically, and legally; water ecological protection will be a core focus; and water resources, water ecology, water environment, and other basin elements will be coordinated. The above measures will provide key support for realizing the goal of a Beautiful China by 2035 [3]. To achieve the goal of the 14th Five-Year Plan for water security in the Haihe River Basin, it is necessary to strengthen the support of relevant scientific and technological research for the water resources guarantee to tackle the areas of water pollution control, water ecological restoration, and water disaster prevention.

At present, research on water security in the Haihe River Basin mainly covers the achievements of 70 years of Haihe River governance from the aspects of water cycle evolution, water pollution control, industrial structure adjustment, etc. [1]. Current research assesses the water security challenges in the Beijing–Tianjin–Hebei region from the perspective of the South-to-North Water Diversion, groundwater overexploitation, and other issues, and puts forward countermeasures [4]. However, prospective research on water security from a macro perspective and oriented to the 2035 development goals should be deepened. Therefore, this review discussed the demand for water security in the Haihe River Basin, and assessed the current status and key problems relating to water resources, water environment, water ecology, and water disasters. This review predicted the change trend of water security in the basin in 2035 and put forward an overall concept and development suggestions for water security in order to provide a basic reference for the research and management of the Haihe River Basin.

2 Challenges in assuring water security in the Haihe River Basin

2.1 Prominent contradiction between the supply and demand of water resources

2.1.1 Severe shortage of water resources in the Haihe River Basin

The Haihe River Basin covers eight provinces and municipalities, including Beijing, Tianjin, Hebei, and Shanxi, with a total area of 3.2×10^5 km^2, accounting for 3.3% of the total land area of the country. The Haihe River Basin bears 8% of the country's arable land and more than 10% of the population and economic aggregate; thus, it plays a key role in the development of the Beijing–Tianjin–Hebei region. However, the shortage of water resources in the Haihe River Basin is severe, with the total amount being approximately 7.348×10^{10} m^3, accounting for only 2.5% of the national total (*China Water Resources Bulletin* data, 2021). The total amount of surface water resources is 4.732×10^{10} m^3, which is significantly higher than the average value from 1956 to 2016, but the total amount of water resources has fluctuated greatly in recent years. With the development of the economy and society in the basin, the total water consumption has exceeded the carrying capacity of the water resources, which is shown by the serious imbalance between supply and demand of the water [5,6]. The increase in water resources utilization has further aggravated the imbalance between the supply and demand of water resources [7].

2.1.2 Regional water transfer lacks risk response strategies, and the water supply network of the Middle Route of the South-to-North Water Diversion Project needs to be improved

The total water supply of Haihe River Basin is approximately 3.72×10^{10} m^3, including groundwater, external transfer water, surface water, and other water supply, which account for 39.7%, 29.5%, 22.3%, and 8.5% of the total water supply, respectively [8]. Therefore, groundwater and external transfer water are the main components of the water supply. In terms of surface water supply, water transferred across river basins plays a very important role in the supply of water resources in the Haihe River Basin. Water storage, water diversion, water lifting projects, and interbasin water transfer account for 12.1%, 19.7%, 11.3%, and 56.9% of water supply, respectively. In terms of underground water supply, shallow water and deep water account for 87.7% and 11.9%, respectively, while brackish water accounts for 0.4% [7,8]. Therefore, external water transfer and interbasin water transfer play a prominent role in supporting the economic and social development of the Haihe River Basin.

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The South-to-North Water Diversion Project has significantly relieved the tense situation of water supply in the Haihe River Basin, but control measures for relevant risks are missing, and the economy of long-distance water transmission needs to be optimized. The water supply scale of the supporting water supply pipeline of the midline project is insufficient, and the water supply capacity of the supporting project does not meet the demand for high-quality development in the region. In addition, the regulation and storage capacity of the planned reservoir are low, the distribution of water supply facilities is uneven, and the security of the water supply is insufficient [1]. Taking Tianjin as an example, the utilization rate of upstream water resources of the South-to-North Water Diversion Project and the Luanhe River Water Diversion Project to Tianjin has gradually increased, resulting in a significant reduction in the amount of water allocated to Tianjin, which has triggered the contradiction between supply and demand of water resources.

2.1.3 The development intensity of regional water resources is high, and the comprehensive utilization technology of unconventional water needs to be strengthened

The development and utilization intensities of water resources in the Haihe River Basin are high. The problem of groundwater overexploitation has continued to intensify from the 1980s to present, with the average annual exploitation volume increasing from 2.118×10^{10} m^3 to 2.499×10^{10} m^3. Overexploitation of groundwater has caused a series of environmental and geological problems, such as ground subsidence, ground fissure, and collapse, which have restricted the sustainable development of the basin's economy and society [8]. With the implementation of the South-to-North Water Diversion Project, the Yellow River Diversion Project, and other external water transfer projects, the groundwater supply in the Haihe River Basin is gradually rising. However, until the groundwater rises to a reasonable level, it remains necessary to carefully monitor groundwater exploitation activities. In 2020, there were 48 groundwater overexploitation areas in the plains area of the Haihe River Basin, with a total area of 1.062×10^5 km^2, in which the deep overexploitation area accounted for 37.5%. The central groundwater level of 26 overexploitation areas has risen to a certain extent [7,8], but there remain 15 overexploitation areas where it has dropped (the drop amplitude of medium-pore deep confined water in Tangshan City, Hebei Province is 10.41 m, and the drop amplitude in other overexploitation areas is < 8 m).

The development of unconventional water resources in the Haihe River Basin still needs to be strengthened. It is necessary to develop technologies for the collection, treatment, and comprehensive utilization of unconventional water, such as brackish water and seawater. In 2020, the total amount of unconventional water resources in the Haihe River Basin was 3.199×10^9 m^3, accounting for only 8.6% of the total water supply in the basin. Among them, the amounts of water obtained via sewage treatment and reuse, brackish water, and water acquired from seawater desalination were 2.976×10^9 m^3, 1.49×10^8 m^3, and 7.4×10^7 m^3, respectively [7,8]. The plains area of the Haihe River Basin is rich in brackish water resources, providing conditions for the development and utilization of unconventional water resources. The development of brackish water technology could increase the effective reuse of unconventional water resources; decrease the overexploitation of deep groundwater, allowing the levels to increase by strengthening the recharge of rainfall/interbasin water transfer, improve the quality of shallow groundwater; and address other environmental and geological problems. After purification and treatment, urban wastewater is reused in municipal areas, lake landscapes, industry, agriculture, etc. for high-efficiency water reclamation. The Tianjin and Shandong areas of the Haihe River Basin need to invest more in the research and development of seawater desalination technology because of their unique geographical location.

2.2 The level of water environment governance urgently needs to improve

2.2.1 The compliance rate of surface water quality in the Haihe River Basin is low

The compliance rate of the surface water's quality in the Haihe River Basin has not reached the national average level, and eutrophication still exists. In 2021, the proportion of sections with good surface water quality (Class I–III) was only 68.4%, while the proportion of sections with water that was inferior to Class V was still 0.4% [9]. Although this meets the requirement of basically eliminating the inferior Class V waterbodies (⩽ 0.6%), the proportion (68.4%) of sections with good water quality is still far below the required national average level (83.4%). With further improvement in the assessment requirements provided by the 14th Five-Year Plan (for example, the number of monitoring sections shall increase by 47% [3]), the amount of surface water reaching the standard requirements in the Haihe River Basin may be inadequate.

As of July 2022, there are still 27 eutrophic lakes and reservoirs in the Haihe River Basin [10]. Among them, Beidagang Reservoir is in a moderately eutrophic state; eight reservoirs, including Dongchang Lake, Yuqiao

Reservoir, Hengshui Lake, and Caiputai Lake, are in a slightly eutrophic state; 16 reservoirs, including Huairou Reservoir and Zaolinzhuang Reservoir, are in a mesotrophic state; and the remainder are in an oligotrophic state [9]. The proportion of slightly eutrophic lakes and reservoirs in the Haihe River Basin is higher than the national average, which shows that there is still a long way to go to control the eutrophication of the basin. Influenced by the incoming water from Luan River and the surrounding catchment area, other parameters of the Yuqiao Reservoir to monitor, for example, mainly include total nitrogen and total phosphorus levels, and the values of indicators, such as soil odor and dimethyl isophenol level, sometimes rise abruptly, negatively impacting the safety of the urban water supply. In particular, the water quality in the Luanhe River, which supplies water to Tianjin, carries a risk of excessive soil odor and algae outbreaks, which directly affect the safety of this water supply [11].

2.2.2 The black and odorous waterbodies in the Haihe River Basin needs to be eliminated

In recent years, the governance of urban black and odorous waterbodies in the Haihe River Basin has achieved remarkable results, with the elimination rate exceeding 80%. However, in some rural areas in the basin, the development of black and odorous water treatment has been slow, and the elimination rate in some provinces is less than 40% [12]. In addition, the local ground elevation is lower than the riverwater level in some cities, and excess rainwater or floodwater needs to be discharged through a pump station. However, some drainage facilities are old and pipelines are silted, resulting in severe flooding due to heavy rainfall. After rain, the quality of the riverwater deteriorates rapidly, causing urban black and odorous water pollution. Therefore, the control of black and odorous waterbodies in the Haihe River Basin is anticipated to be a long-term project.

2.2.3 The sewage treatment capacity needs to be improved

The Haihe River Basin is the main grain production area in the north of China, and the proportion of water used for agriculture is consistently more than 60% [1]. Therefore, problems relating to sewage treatment in rural areas are severe. In 2020, the proportion of sewage that was treated in the Haihe River Basin was only 36%, which was far from the target of more than 60% of rural domestic sewage being treated in the 14th Five-Year Plan period [3]. The annual average operating load rate of sewage treatment plants exceeds 90% in some cities in the region; thus, their expansion and improvement are required. In recent years, it has only been possible to decrease the production load and increase reagent consumption to ensure better effluent water quality, resulting in the capacity utilization rate only being maintained at approximately 70%. Therefore, in-depth transformation is required [11]. In addition, there are shortcomings of the pipe network in urban sewage collection. The construction level and management ability of the sewage pipe network are low. For example, there remains approximately a 1.53 km^2 area in which rain and sewage confluence and 1919 mixed connection points are present in the central urban area of Tianjin. The drainage into the river after rain affects the water quality of the basin [11]. The problems of overflow pollution control, rain–sewage separation, and clean–sewage separation need to be solved urgently.

2.3 Water ecological environment protection needs to be strengthened

2.3.1 Obvious degradation of water ecological function and biodiversity

With the gradual increase of water demand for economic and social development, the development and utilization rate of water resources in the Haihe River Basin has exceeded the reasonable bearing range, which has aggravated water environmental pollution and damaged the water ecosystem. Excessive development and utilization of water resources have also led to serious degradation of ecological functions, dramatic reduction of wetland areas, and impacts on biodiversity. In the Haihe River Basin, the ecological environment quality of more than half of the rivers is at a medium or low level, making them less suitable survival and reproduction habitats for various populations and communities. More than 30% of rivers in the Haihe River Basin have extremely poor ecological environment quality, resulting in the dilution of aquatic species and low diversity of benthic communities [7]. For example, the average Shannon–Wiener diversity index of fish communities in the Haihe River Basin is only 1.53, which reflects the decline in the number of fish species, the decline of large- and medium-sized fish resources, the simplification and miniaturization of dominant populations, and the low level of biodiversity in the basin. In terms of fish community structure, the number of sensitive species present has decreased, and the number of species that are resistant to pollution (such as Dali Lake Plateau loach and catfish) has increased [13].

2.3.2 The water system is poorly connected

At present, the load capacity of the water environment in the Haihe River Basin is weak, the connectivity

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facilities of the rivers and lakes in the city are insufficient, and some water circulation connectivity systems fail to function at an acceptable level, leading to serious phenomena, such as river channels drying up and the obvious shrinkage of wetlands. The ecological flow in the basin is not guaranteed, and the upstream and headwaters of most rivers are at medium risk of being cut off. The two water circulation communication systems from the Haihe River in the central urban area to the Beidagang Wetland in the south and Qilihai Wetland in the north have not yet been optimized. Although the east, middle, and west lines of the South-to-North Water Diversion Project have been fully implemented, only the West Longitudinal North Canal–Weihe River–South Canal has been completed, while the East Longitudinal Ji Canal–North Trunk Canal of the Central Bridge–North Trunk Canal of the Central Bridge of the Machangjian River as well as the Longitudinal Luanhe River–Haihe River–Hongni River have not been completed yet [11]. Channelization and hardening of natural rivers with the aim of developing a single flood control function are common, and it is necessary to fully restore the ecosystem function of the Haihe River Basin.

2.3.3 Lack of attention to the application of new toxic pollutants in the environment

For a long time, water pollution control has focused on aerobic organic, nitrogen, and phosphorus pollution, while attention on toxic organics and new pollutants has been lacking. Relevant assessments and monitoring levels need to be improved, and risk prevention measures are relatively weak. In 2018, the average content of drugs and personal care products in the water source area of each province in the Haihe River Basin was the highest in Shandong Province (78.3 ng/L), lowest in Beijing City (30.0 ng/L), and at a middle level in Tianjin City (45.6 ng/L) and Hebei Province (50.6 ng/L). Sulfa antibiotics were detected in surface water sources in Beijing, Tianjin, and Shandong Province; tetracycline antibiotics were detected in water sources in Tianjin, Hebei, and Shandong Province; macrolide antibiotics were only partially detected in water sources in Shandong Province; and quinolones were only partially detected in water sources in Hebei Province [14]. This shows that the levels of new pollutants in the water sources of the Haihe River Basin should not be ignored. However, at present, there remains a lack of attention on new toxic pollutants. No assessment, monitoring, or emission standards for new pollutants have been formed. The existing management and removal technologies for new toxic pollutants are poor [15], which affects the safety of drinking water in the Haihe River Basin.

2.4 Coexistence of old and new problems in flood control and disaster reduction

China has always attached importance to the management of water conservancy weak links, such as large- and medium-sized reservoirs, 15 main backbone rivers, and small- and medium-sized rivers in the Haihe River Basin. However, less than 50% of the backbone rivers meet the flood control standard. In particular, work to reinforce small yet dangerous reservoirs with gates and the construction of flood storage areas have been slow [7]. The combination of new and old problems in the basin, such as a complex river system, a large hydrological change trend, difficult reservoir operation, aging and disrepair of embankments, and siltation and congestion of river channels, has made the flood discharge capacity worse. In addition, in the basin, there are obvious weaknesses in urban drainage facilities, and in some cities these are outdated. The lack of urban waterlogging drainage capacity has affected the level of urban development, residents' quality of life, and safe travel, and serious urban waterlogging can endanger residents' life, health, and safety.

3 Prediction of water security trends in the Haihe River Basin in 2035

3.1 Characteristics of the change in water quantity and quality in the Haihe River Basin over the last 20 years

The total water consumption of the major provinces in the Haihe River Basin (Beijing, Tianjin, and Hebei) fluctuates, decreasing from 2.553×10^{10} m^3 in 2003 to 2.5×10^{10} m^3 in 2020, but increasing to 2.61×10^{10} m^3 from 2006 to 2007 [16]. The per capita water consumption shows a gradual downward trend, reaching its peak in 2005 (275 m^3/a), decreasing to 251 m^3/a in 2010, and fluctuating between 248–252 m^3/a afterward. This information shows that the serious shortage of water resources in the Haihe River Basin has not been eliminated.

The composition of water use in the Haihe River Basin is significantly different from that in other areas of China. From the perspective of water demand, the current water supply in the Haihe River Basin mainly comes from groundwater, supplemented by interbasin water transfer, which plays an important role in supporting the economic development of the basin. From the perspective of water use composition, the Haihe River Basin mainly uses water for agriculture (accounting for 53.6%), followed by water for domestic and artificial ecological environments and water for artificial ecological environment supplementation (accounting for 17.7% and 17.6%, respectively), and industrial water is the lowest (accounting for 11.1%) [8].

In terms of water quality, the Haihe River Basin has improved significantly. According to the monitoring data of river and lake sections, the proportion of Class III and above waterbodies has increased from 22% in 2006 to 68.4% in 2021, and the proportion of inferior Class V waterbodies has decreased from 57% in 2006 to 0.4% in 2021.

3.2 Prediction of water quantity and quality of the Haihe River Basin in 2035

Using the environmental statistics data from 2003 to 2020, a quadratic polynomial regression equation was established between the gross domestic product (GDP) and annual per capita water consumption. A logarithmic regression equation was also established between the investment in environmental pollution control and the proportion of Class III and above waterbodies. Five path scenarios of sharing social economy were referred to [17] and predictions were based on the intermediate path. By 2035, the total population of the major provinces and municipalities in the Haihe River Basin (Beijing, Tianjin, and Hebei) will be approximately 114.27 million, which is an increase of 1.4% compared with 2020.

Using the relationship equation between the total GDP and the per capita water consumption, three scenarios have been set: the per capita water consumption of the basin remains unchanged in 2020, the highest per capita water consumption between 2003 and 2020, and the per capita water consumption continues to decline according to the current range. It is predicted that the total water consumption under each scenario in 2035 will be 4.708×10^{10} m^3, 5.211×10^{10} m^3, and 2.42×10^{10} m^3, respectively.

Based on the fitting relationship between the investment in environmental pollution control and the proportion of Class III and above waterbodies, three future simulation scenarios have been set (the proportion of GDP invested in environmental protection is 1.0%, 1.5%, and 2%, respectively). It is predicted that the proportion of Class III and above waterbodies in each scenario in 2035 will be 86.15%–94.7%. This figure continues to increase compared with that of 2000–2020, but the growth rate decreases.

4 Overall concept of water security in the Haihe River Basin for 2035

Focusing on the demand for water security in the Haihe River Basin by 2035 and based on the characteristics of regional economic and social development, it is important to demonstrate a method for reaching water security in the basin. The following capacities need to be developed: (1) water resources system allocation and efficient utilization; (2) water environment quality improvement and comprehensive management; (3) watershed ecological management and restoration; and (4) water disaster prevention and emergency response. The evolution law of water resources in the basin should be understood, effective monitoring systems and information networks should be constructed, comprehensive and efficient response measures and governance plans should be put in place, and the water treatment goal for the 14th Five-Year Plan period should be realized.

In terms of water resources, a water supply security system should be established that features economy, efficiency, and urban-rural integration. Saving water should be a priority, as should strengthening rigid constraints on water resources, implementing dual control over the total amount and intensity of water use, and highlighting key water-saving directions, such as industrial water conservation and emission reduction, agricultural water conservation and efficiency enhancement, and urban water conservation and loss reduction. The carrying capacity of water resources and the water environment in the Haihe River Basin should be improved, ecological flow management should be brought into the scope of water resources management, and a healthy ecological flow should be ensured for the basin. The goal is that by 2035, the utilization efficiency of water resources in the Haihe River Basin will have reached the leading level in China, and the utilization rate of unconventional water resources will have reached 50%. In addition, a water-saving basin will have been created, and a new water supply pattern of multisource supplement and urban-rural coordination will have been comprehensively formed [11].

In terms of the water environment, the treatment level of industrial sources and rural domestic sewage should be improved significantly, and agricultural non-point source and urban non-point source pollution control should be easier. Safe treatment of drinking water will be carried out, the management of drinking water sources and the ability to ensure drinking water safety will be strengthened, and a smart and efficient water treatment security system will have been built. By 2035, the number of nationally controlled excellent quality waterbody sections in the Haihe River Basin will have increased steadily, and the proportion of Class I–III surface waterbodies will have reached 95%. The proportion of centralized drinking water sources in cities at the county level and above that meet or exceed Class III will reach 100%. The proportion that will reach the standard for major indicators of effluent

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from sewage treatment plants will exceed 98%.

In terms of water ecology, the self-purification capacity and biodiversity of the Haihe River Basin will be significantly improved, aquatic vegetation in the water area will be restored, and vegetation in the river lake buffer zone will be protected, so as to build a water ecological security system. According to the management and control requirements of the ecological environment function of the Haihe River Basin, the total amount of nutrients in the lake will be controlled and the loads of nitrogen and phosphorus will be reduced to comprehensively improve the water ecological environment. The focus on harmony between people and the water ecological environment will reflect residents' yearning for beautiful rivers and lakes, and improve the quality of the ecological environment. By 2035, a green river ecological corridor system will have been formed in the Haihe River Basin, the governance of adjacent rivers and lakes, such as the South and North Canal, will have been completed, and the biodiversity of the basin will have been restored. Ecological restoration and cultural construction should also be integrated, and a green basin in North China should be built.

In terms of water disaster prevention, the ability to prevent and mitigate disasters should be effectively enhanced, weak links in flood control should be comprehensively eliminated, and the vision of a beautiful Haihe River should be realized. By 2035, the rate of reaching the standard of levees for Class I flood discharge channels in the Haihe River Basin should be higher than 84% [11], and an urban drainage and waterlogging prevention engineering system should be built. The proportion of areas with less than a one-year drainage standard in the central urban area and areas with a three-year drainage standard should be increased from 20% to 58%. Some breakthrough technologies should be applied in the Haihe River Basin, such as flood forecasting, urban rainwater collection and drainage, and flood control security systems that integrate storage, discharge, and drainage and govern drought, flood, and tide simultaneously.

5 Suggestions for assuring water security in the Haihe River Basin

5.1 Proposing new strategies for water resource conservation and efficient utilization

On the premise of strengthening water conservation, water resources in the Haihe River Basin should be allocated based on research findings. The water resource management system of quantity and efficiency double control should be continuously improved, and the construction of a "two vertical and six horizontal" water resource supply pattern and a multisource complementary water allocation system should be accelerated. Methods of "management, regulation, and supply" should be carried out simultaneously, water conservation should be promoted, and the independent guarantee of water resources and the load capacity of water resources in the basin should be improved to ensure the safety of the water supply in the basin.

The efficient recycling of water resources should be strengthened, the intelligence level of the pipe network leakage operation control should be improved, key breakthrough technology for water-saving irrigation precision control should be developed, and water-saving irrigation, precision control, and other equipment should be constructed. Water intake and use should be strictly managed and the safety supervision of the whole water supply should be improved from source to end. The efficient allocation of water resources, optimal use of water, reasonable allocation of external water transfer, and development of accurate regulation and control technology of interbasin water resources should be realized. Surface water should be stored and fully utilized, and the use of renewable water in ecological agriculture should be increased. The collection, treatment, and utilization of unconventional water, such as seawater, should be strengthened, the scale of seawater desalination should be expanded, a new strategy of seawater supplementation for drinking water should be formed, and the distribution, supply, and comprehensive utilization of unconventional water resources should be promoted.

5.2 Ensuring drinking water safety and improving water treatment capacity

The water environment maintenance of the Haihe River Basin is mainly divided into the following two stages: (1) In view of the challenge of the combined pollution of conventional, toxic, and harmful substances in waterbodies, a basic database of water quality in river basins should be established according to the levels of the river basins, key water sources, and comprehensive utilization processes. The combined pollution process of key water sources should be explored, new principles and methods of pollution control should be developed, and new technologies for drinking water safety and polluted water recycling should be trialed. (2) In view of risks of water pollution to humans and ecosystems, the compound regulation mechanism of river basin waterbodies should be studied, and a technical system for assuring water quality safety in the process of the water cycle should be built.

To ensure the safety of water supplies, the safety assurance of drinking water, advanced treatment and reuse of sewage, and control of new pollutants should be key focuses. An inventory survey of new pollutants in the Haihe River Basin should be promoted, an ecological and health risk assessment model should be established based on new pollutants, water quality indicators of drinking water quality standards should be improved to take into account new pollutants, the development of green water purification technologies for new pollutants should be accelerated, a new pollutant standard formulation and integrated management information system should be built, and the long-term construction of a new pollutant treatment system should be promoted further. Digital, intelligent, and learning-based water supply systems should be developed; accurate, fast, and reliable comprehensive early warning methods for drinking water risks and key technologies for online monitoring should be constructed; and short-process and low-carbon drinking water purification processes should be used. Seamless emergency measures and rapid water supply technology for emergencies will be proposed. The research and development of robots and other intelligent means to detect the corrosion and leakage areas of a water supply network and repair or replace seriously corroded pipes will be accelerated. A mechanism for all-round and full process water quality safety risk management and control "from the source to the end" will be established, and the safety of the whole process for drinking water supplies will be ensured. The technology development strategy of "carbon reduction and efficiency enhancement, energy self-sufficiency, and resource recycling" will be adopted for advanced treatment and reuse of urban sewage, and technology of carbon reduction and efficiency enhancement will be developed. New multifunctional membrane materials and equipment should also be created. The strategy of "sewage cascade purification–subsection processing–cascade utilization" is recommended.

5.3 Building a water ecological pattern featuring harmony between humans and water

The idea of comprehensive protection and systematic management should be adopted, a high-quality ecological water network should be built, and the comprehensive management of "six rivers and five lakes" in the Haihe River Basin should be strengthened. Water should be used as the core element to promote harmony between humans and water. The coordinated governance of Beijing, Tianjin, and Hebei should be highlighted, the joint prevention and control of the upstream and downstream of transprovincial rivers should be promoted, and the cogovernance of internal and external pollution of rivers entering the sea should be strengthened. A chief system for rivers and lakes should be implemented, and the water ecological space should be strictly controlled. Key factors, such as multidimensional regulation, overextraction control of groundwater, and long-term conservation of water ecological restoration, will be tackled in the Haihe River Basin. A multifunctional technical model for water ecological restoration as well as post-assessment criteria for the effect of ecological restoration in the basin will be developed.

In the early stage, source supplementation will be a key focus, and surplus water will be used in the east/middle route of the South-to-North Water Diversion Project to conduct ecological water transfer to key rivers and lakes in the Beijing–Tianjin–Hebei region. Moreover, the comprehensive control of groundwater overexploitation in North China will be simultaneously implemented. After the east/middle route of the South-to-North Water Diversion Project is connected with the river system, and the middle route of the South-to-North Water Diversion Project and the joint deployment of large- and medium-sized reservoirs along the line are completed, the shallow groundwater and river ecological water will be fully compensated. After the completion of the follow-up projects of the South-to-North Water Diversion Project, plans for water resource allocation can be changed, priority can be given to the use of river channel water, and deep groundwater levels and reserve functions can be restored. Through the ecological restoration of water in the basin, the hydraulic, water quality, ecological, landscape, and recreation functions of the rivers can be maximized. In this process, the assessment technologies and standards that adapt to the actual ecological restoration of the Haihe River Basin will be formulated in time to promote water ecological environment quality monitoring and health assessments, and maintain the health of the basin ecosystem.

5.4 Establishing water disaster prediction and response mechanisms

A flood control security system that integrates storage and discharge, and addresses both drought and flooding will be built. The ability of the Haihe River Basin to prevent and mitigate disasters, especially through early warning, forecasting, and emergency responses before disasters, will be comprehensively improved. Flood control works shall meet an overall standard and improve the ability of the Haihe River Basin to resist environmental and geological disasters that involve water. The flood control responsibility system and organizational support capacity will be improved, as will the response capacity and speed for sudden emergencies.

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In terms of scientific research, strengthening the collection of basic data on hydrology, water environment, meteorology, soil, and other environmental media in the Haihe River Basin is of great importance, as is establishing a more comprehensive database. Systematically assessing the impact of climate change, human activities, and other factors on the spatiotemporal distribution of water resources in the Haihe River Basin is of great significance. Focusing on the spatiotemporal characteristics and dynamic driving mechanism of water resources distribution will be beneficial. Focusing on the optimal allocation and intensive and safe use of water resources will also be of great importance. Engineering technology for the regulation and control of interbasin water resources should be developed, and early warning, prediction, and response mechanisms for flooding disasters should be improved. Green rainwater and flood control design and management technology should be developed, and the effective connection between infrastructure and the original ecological background of rivers and lakes should be strengthened based on the characteristics of cities in the basin. The design and construction of advanced sponge cities should be carried out according to local conditions, and methods of "infiltration, stagnation, storage, purification, use, and drainage" should be comprehensively adopted to improve the collection and utilization efficiency of rainwater resources. An urban nonpoint source pollution evaluation and monitoring system should be established, research relating to prevention and control technology of nonpoint source pollution of rainfall runoff should be deepened, and new purification materials and devices should be developed.

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