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Strategies for Guaranteeing Drinking Water Safety in the Yangtze River Delta

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Abstract: Drinking water safety is related to national economy and people's livelihood. China has always attached great importance to guaranteeing drinking water safety. Since China's reform and opening up in 1978, water environmental pollution has brought great challenges to drinking water safety in the Yangtze River Delta region owing to active economic development and high population density in the region. After over ten years of development, the overall level for guaranteeing drinking water safety in the Yangtze River Delta region has significantly improved, effectively promoting the coordinated and sustainable development of the region. However, as people's requirements for water quality and health gradually increase, work for guaranteeing drinking water safety in the megalopolis agglomeration of Yangtze River Delta faces various challenges. In this article, we analyze the water quality characteristics of typical water sources in the Yangtze River Delta region, and summarize the achievements in urban drinking water safety assurance of the region. Suggestions are proposed from two dimensions (i.e., management and technology) and three aspects (i.e., water source, water treatment plant, and secondary water supply), including improving the ecological compensation mechanism, collaboratively revising water quality standards, developing green and efficient purification technologies, and innovating the water supply management model. These strategies can provide a reference for assuring drinking water safety and promoting regional integration in the Yangtze River Delta and other key regions.

Keywords: drinking water; Yangtze Delta; safety guarantee; micro-pollutants; emerging contaminants; green development; smart water supply

1 Introduction

Located at the downstream of the Yangtze River, the Yangtze River Delta is one of the regions with the rapidest economic development, the highest degree of openness, and the highest innovation capacity in China, and has a pivotal strategic position in the overall national modernization and all-round opening pattern [1]. Since the reform and opening up in 1978, with the rapid development of the economy and the population agglomeration in the Yangtze River Delta, the pollution levels in the watershed has been increasing. Various known and unknown, natural and anthropogenic, traditional and emerging, and primary and secondary pollutants have entered the aquatic environments, aggravating the deterioration of water quality in the basin and the eutrophication of the lakes. As a result, the bloom of cyanobacteria in the Taihu Lake occurs frequently and the issues concerning complex

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pollution, sudden pollution, and transboundary pollution are significant, which further affects the drinking water sources and the safety of regional water supply.

The CPC Central Committee and the State Council have attached great importance to the ecological environment protection, water pollution prevention, and drinking water safety. In recent years, a suite of new ideas and measures have been put forward. Since 2015, a series of major decisions, projects and plans have been issued, such as *Opinions on Accelerating the Construction of Ecological Civilization*, *Overall Plan for the Reform of Ecological Civilization System*, and *Action Plan for Prevention and Control of Water Pollution* (referred to as "Water Ten"). In 2017, the Standing Committee of the 12th National People's Congress passed the third revision of the *Law of the People's Republic of China on Prevention and Control of Water Pollution*, which standardized and legalized the systems and measures established in the "Water Ten" and also provided important legal safeguards to ensure the safety of urban water supply in China. In 2019, the State Council issued the *Outline of the Regional Integration Development Plan of the Yangtze River Delta*, which proposed to strengthen the joint protection and management of the ecological environment and promote the coordinated management of the environment. Besides, Shanghai, Jiangsu Province and Zhejiang Province should jointly formulate and implement the laws and regulations concerning the protection of drinking water sources in the demonstration area, enhance the protection of cross-regional rivers and lakes that serve as the source water, explore and establish mechanisms for the linkage of raw water and emergency supply of water resources in the Yangtze River Delta, and improve the ability to guarantee the safety of water supply, thus laying a policy foundation for collaborative protection of drinking water safety from the regional level [1].

In recent years, the technologies and achievements developed by the Major Science and Technology Program for Water Pollution Control and Treatment (referred to as "Water Project") have played a comprehensive supporting role in improving drinking water quality and ensuring that water quality meet the requirements of standards in China, and have established a "From Source to Tap" drinking water safety guarantee technology system, which has greatly promoted the scientific and technological level of drinking water research fields in China [2]. The Yangtze River Delta is the frontier of China's reform and opening up and also an important platform for China's high-quality development. The water quality characteristics of this region and the work related to drinking water safety protection are typical and representative. Thus, in order to provide references for the Yangtze River Delta mega-city agglomeration and other key regions, this paper introduces the typical water quality characteristics of the Yangtze River Delta, summarizes and analyzes the achievements and challenges concerning urban drinking water security work, and proposes some measures and suggestions accordingly.

2 Development status of drinking water safety management in the Yangtze River Delta

2.1 Water quality characteristics of typical water sources in the Yangtze River Delta

Located at the downstream of the Yangtze River Basin, the Yangtze River Delta region is connected to rivers, lakes, and seas, and has criss-crossing water systems and abundant water volume. However, the source water quality in this region is relatively poor. According to the characteristics of water quality, Yangtze River Delta water sources can be divided into three types, namely, river-type, lake-type, and river network-type water sources (Fig. 1).

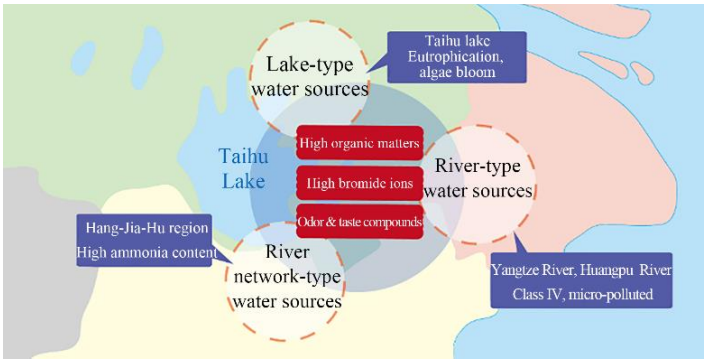

Fig. 1. Characteristics of water quality in the Yangtze River Delta.

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Water sources including the Yangtze River, Huangpu River, and other river-type reservoirs, which are commonly used in Shanghai, have suffered from algae-derived odor and organic pollution for a long time. Since Shanghai is located at the downstream of the Yangtze River, micro-pollutants such as pesticides and antibiotics are frequently detected in the water sources here. A study investigated the occurrence of micro-pollutants in the source water of Shanghai, and found that the detection rate of atrazine, a typical pesticide, in the Yangtze River and Huangpu River reached 100 % and the average concentration were 20 ng/L and 80 ng/L, respectively [3]. Besides, among the common antibiotics, the concentrations and detection rates of sulfonamides and macrolide antibiotics were the highest.

The lake-type water sources, which are commonly used as the raw water of drinking water treatment plants (DWTPs) in the southern Jiangsu Province (e.g., Suzhou and Wuxi), are mainly impacted by algae bloom and organic matter pollution. The annual average density of algae in the raw water of some DWTPs is higher than 1×10^7/L, and the high-laden algae period is from July to August, with the algae density reaching 2×10^7–8×10^7/L. Owing to the high content of algae, the levels of algae-derived secondary metabolites, algae-derived odorous compounds, and the precursors of nitrogenous disinfection by-products in lake-type water sources are relatively high. Based on the results of investigations on several DWTPs that use Taihu Lake as a water source, researchers found that the levels of haloacetonitrile (a class of nitrogenous disinfection by-products) precursors in the raw water of selected DWTPs were high, with a formation potential of haloacetonitriles up to 32 μg/L [4].

Hangjiahu in the northern Zhejiang Province, a typical river network-type water source, is located at the southern part of the Taihu Lake Basin and belongs to the lower reaches of the Taihu Lake Basin, and thus is greatly affected by upstream water. Meanwhile, the river network is intertwined, and the slow flow rate of the rivers makes the self-purification ability of water bodies decrease, and the ammonia nitrogen and organic matter pollution in the water sources is severe. A survey found that the ammonia nitrogen content in the raw water of some river network-type DWTPs was higher than 5 mg/L, and the ammonia nitrogen concentration was lower in summer while higher in winter [5].

At the end of 2006, the Ministry of Health, together with other relevant departments, revised and promulgated the “Standards for drinking water quality” (GB 5749–2006), which significantly increased the amount of water quality indicators and improved the limit requirements. This standard not only brought new historical opportunities for the improvement of China’s drinking water security assurance capacity, but also provided important standard support for the national strategic needs of ensuring the safety of residents’ drinking water. There is no exception for the Yangtze River Delta, and fully meeting the requirements of drinking water quality in the region is imperative. Before 2007, the urban DWTPs in the Yangtze River Delta mostly applied conventional treatment processes and the management methods were relatively extensive, and thus it was difficult to meet the standards of drinking water quality. The safety assurance of drinking water in the Yangtze River Delta was facing great challenges.

2.2 Current status of drinking water safety in Yangtze River Delta

For over a decade, China’s urban drinking water safety guarantee capacity has made great progress. The technical ability of water source protection, water purification, safe distribution, monitoring and early warning, emergency response, safety management, and other aspects has been significantly improved. The drinking water safety guarantee technology system “from source to tap” has been initially formed, and the large-scale application and business operation have been realized, effectively supporting the improvement of drinking water quality and ensuring the safety of drinking water. The compliance rate of finished water in China has increased from 58.2% (in 2009) to 96% in recent years [6]. Since the 11th Five-Year Plan, the Yangtze River Delta, which was the main implementation area of the Water Project, has conducted key technology development and demonstration application for drinking water safety guarantee through research and development of innovative technologies. These efforts were jointly made by governments, industries, universities, and research institutes. Through the research and demonstration application, multi-level barrier technologies with ozone–activated carbon as the core have been formed (Fig. 2). Meanwhile, the management model was innovated and a series of important technical guidelines and standards were compiled and issued, such as the first local drinking water quality standard in Shanghai “Standards for drinking water quality” (DB 31/ T1091–2018) and “Standards of the key water quality parameters for urban water treatment plants in Jiangsu” (DB 32T 701–2019), as well as *Guidelines of Ozone–Biological Activated Carbon Process Operation and Management for Urban Water Treatment Plants in Jiangsu*,

which effectively supported the overall improvement of drinking water safety guarantee capabilities in the Yangtze River Delta [7].

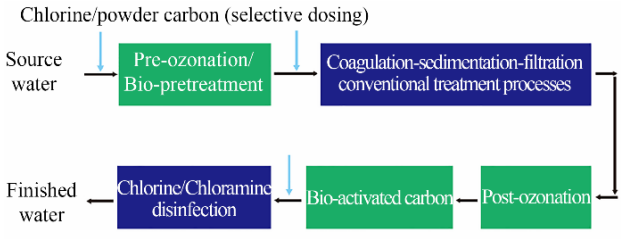

Fig. 2. Typical drinking water treatment processes in the Yangtze River Delta region.

As a megacity, Shanghai has built water sources consisting of two rivers (the Yangtze and Huangpu River) and four reservoirs (Qingcaosha, Chenhang, Dongfengxisha, and Jinze Reservoir) to enhance the security of urban water supply through the efforts of over a decade The Yangtze River is the main water source, accounting for 70% of the city's water supply, while the Huangpu River is the alternative water source, accounting for 30% of the city's water supply. The raw water of DWTPs in Shanghai shows a pattern of "two rivers, centralized intake, reservoir supply, and network scheduling" [8], significantly improving the risk tolerance of water sources in this megacity of 24 million people. Through water supply intensification as well as orderly and deep upgrade of DWTPs, the ability of DWTPs to deal with algae, odor-causing substances, and typical disinfection by-products has been improved, and finished water quality has been significantly improved, satisfying the requirements of the "Standards for drinking water quality" (GB 5749–2006) and the local drinking water quality standard in Shanghai "Standards for drinking water quality" (DB 31/T1091–2018), and the long-standing problem concerning odor and taste compounds in drinking water of Shanghai has been solved.

Jiangsu Province has several water sources in the Taihu Lake. Both of Wuxi and Suzhou mainly use the Taihu Lake as their drinking water source and are typical lake-based water source cities. According to the quality characteristics of source water in the Taihu Lake and the feature of water supply, Jiangsu Province has broken through the limitation of traditional drinking water purification mode (i.e. water treatment in DWTPs) and developed a multi-source optimal scheduling technology, in which the use of alternative water sources and the pretreatment of raw water are combined and coupled. Besides, with the aim of controlling algae and organic matters, pretreatment and advanced treatment technologies have been developed and a novel process of coordinated purification and multi-barrier drinking water treatment with ozone–biological activated carbon as the core has been established (Fig. 2). The comprehensive demonstration was conducted in 13 DWTPs (4.7×10^6 m^3/d) with the Taihu Lake water as the water source in Wuxi, Suzhou, Wujiang and other cities. The finished water quality steadily met the requirements of "Standards for drinking water quality" (GB 5749–2006) and "Standards of the key water quality parameters for urban water treatment plants in Jiangsu" (DB 32 T 3701–2019), benefiting over 10 million people. Meanwhile, the application was comprehensively promoted around the Taihu Lake in Jiangsu Province and the overall drinking water safety guarantee capacity in the Taihu Lake Basin in Jiangsu was improved. Besides, the water quality problems strongly complained by the residences, such as algae, odor compounds, and typical disinfection by-products have been nearly solved [9].

Located at the downstream of the Taihu Lake Basin, Jiaxing is a typical city using river network-type water sources in Zhejiang Province. The river network is intertwined and the terrain is flat. Besides, the flow rate of rivers is slow and the quality of source water here ranged from inferior Class V to Class IV before. Owing to the characteristics of heavily polluted river network-type water sources, including a high ammonia nitrogen content and high oxygen demand, Jiaxing was devoted to the development and demonstration of biological–ecological wetland restoration technologies for water sources, biological pretreatment technologies for raw water, as well as enhanced conventional treatment and advanced treatment technologies and so on. As a result, the technology system coupling biological and ecological restoration and treatment, which is used to treat river network-type water sources with high ammonia nitrogen and high organic matter content, has been formed. The first organized wetland treatment project treating micro-polluted water sources has been built in China and the quality of drinking water produced from demonstration DWTPs could steadily meet the "Standards for Drinking Water Quality" (GB 5749–2006).

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3 Challenges of drinking water security in the Yangtze River Delta

3.1 Lack of substantive system for transboundary drinking water source protection

The industrial structure, economic development strategy, and geographical location of Jiangsu, Zhejiang, and Shanghai determine the different positioning of water functions. For example, the Taipu River, which connects the East Taihu Lake and the Huangpu River, flows through Wujiang in Jiangsu Province, Jiashan in Zhejiang Province, Qingpu in Shanghai and other places. Although the cities abovementioned use the same drinking water sources, the functional positioning of the Taipu River in the upper and lower reaches is different. The Taipu River in Jiangsu section is mainly used as a floodway, transportation channel, and water source for industry and agriculture, with numerous textile printing and dyeing industries along the river. However, the downstream of the Taipu River serves as an important water source for Shanghai Jinze Reservoir and Zhejiang Jiashan. The transboundary drinking water sources have a feature that the water suppliers and the water receivers belong to different administrative regions, as well as the water conservation area and the catchment area. Because the water supply areas and water source conservation areas have to sacrifice local economic and social development to protect and remediate water sources, and thus are not very active in water source protection. There is a conflict of interest between upstream and downstream areas, which brings difficulties to the implementation of cross-provincial boundary water source protection. Besides, unorderly legislation in this region and the lack of substantive system exist [10].

3.2 Prevalence of trace contaminant complex pollution in water sources

Water source pollution is widespread in China, and many types of pollutants with complicated composition exist in China's water sources. Trace contaminant complex pollution is the typical water quality characteristics of the Yangtze River Delta. A series of unregulated micro-pollutants (also known as emerging pollutants), including pesticides, antibiotics and other drugs, bisphenols/perfluorinated and other industrial products, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, algae toxins and other trace organic pollutants have been detected in the Yangtze River water sources and the Huangpu River water sources in Shanghai, Taihu Lake water sources in Jiangsu Province, river network-type water sources in Jiaxing, Zhejiang Province, leading to complex pollution. The origins of pollutants can be generally divided into the following categories.

(1) Allochthonous pollution. Agricultural non-point source pollution and industrial/domestic point source pollution are generally classified as allochthonous pollution. For example, the unscientific abuse of pesticides, the inappropriate discharge of livestock and poultry manure, and the abuse of aquaculture bait drugs can lead to the existence of pesticides, antibiotics, and other drugs in the water sources. Owing to the low treatment efficiency of industrial wastewater and domestic sewage in the upper reaches of the river, pollutants such as industrial compounds, personal care products, and their intermediates would be discharged into the aquatic environments.

(2) Autochthonous pollution. Since the levels of nitrogen, phosphorus, and other pollutants discharged from upstream area exceed the environmental capacity of the receiving water bodies, the Taihu Lake, Qingcaosha Reservoir (the Yangtze River water source), Jinze Reservoir (the Huangpu River water source), and other shallow lakes and reservoirs water sources are faced with severe eutrophication problems. Algae-derived odor compounds, algae toxins, and other metabolites are frequently detected.

(3) Secondary pollution. Part of the primary pollutants in the water sources would enter into the DWTPs and react with chemical agents such as disinfectants and oxidants. During the reaction, the structure and state of primary pollutants are changed and the secondary pollutants are formed. For example, although the concentrations of some antibiotics are significantly reduced after the oxidation process or disinfection process in DWTPs, they might be transformed into secondary products with unknown toxicity.

The concentrations of these unregulated trace pollutants in water sources are usually at the nanogram (ng/L) to microgram (μg/L) level. Although these pollutants would not cause sudden harm in the short term owing to their low levels, they often coexist with pollutants and may have synergistic or antagonistic effects. The complex pollution of trace contaminants has gradually become one of the main water quality problems of concern in the cities at all levels [11].

3.3 Long water treatment processes and high dose of chemicals

China's water pollution control work is a long-term and arduous task, and there is no exception for the Yangtze River Delta region. Since the problem concerning complex pollution in water sources cannot be completely solved

in a short period of time, DWTPs have to increase and extend the treatment processes and add oxidants, coagulants, coagulant aids, disinfectants, and other chemicals to ensure that the water quality meets the standards. The extension of the processes and the addition of materials significantly improve the quality of finished water when treating the polluted water sources whereas lead to the occurrence of some inorganic and organic secondary pollutants [12,13].

3.4 Safety concerns about tap water

In China, finished water from DWTPs will be firstly stored in the pools or tanks and then be pressurized to the homes of residents, that is, secondary water supply. As a result of the rapid development of high-rise buildings in the Yangtze River Delta, the coexistence of new and old neighborhoods, as well as the numerous and scattered water tanks and pools with long water age, high water temperature, and poor airtightness, there is a series of problems concerning lining materials, cleaning and disinfection, operation and maintenance, and management, posing risks to the safety of tap water.

4 Suggestions for safe management of drinking water in the Yangtze River Delta

To cope with the above problems and challenges, strategic suggestions are proposed in two dimensions (i.e., management and technology) and three aspects (i.e., water sources, DWTPs, and distribution systems) as follows.

4.1 Consummating ecological compensation system to facilitate the process of water source protection

The *Outline of the Regional Integration Development Plan of the Yangtze River Delta* issued in 2019 explicitly required that an inter-basin and inter-regional ecological compensation system and a regional environmental governance linkage system should be supplemented [1]. The *Water Security Plan for the Integrated Development of the Yangtze River Delta Region* issued in 2021 also proposed to build an interconnected water supply guarantee system and improve the urban and rural water supply guarantee capacity [14]. It is suggested to actively organize pilot ecological compensation programmes for transboundary water sources in the Yangtze River Delta region. Taking the Taipu River as an example, it is difficult to ensure the effectiveness in managing the Taipu River by only one city or one county. On the basis of national legislation such as *Law of the People's Republic of China on Prevention and Control of Water Pollution*, *Taihu River Basin Management Regulations*, and *Yangtze River Protection Law*, Shanghai, Jiangsu, and Zhejiang should continue to strengthen joint protection and governance of water sources by establishing a system featuring cost sharing, benefit sharing, and cooperative governance between upstream and downstream areas [15]. Besides, they should explore a scientific monitoring, evaluation, assessment and compensation system. Based on the corresponding local legislation such as *Regulations on the Protection of Drinking Water Sources in Shanghai*, *Decision of the Standing Committee of the People's Congress of Jiangsu Province on Strengthening the Protection of Drinking Water Sources*, and *Regulations on the Protection of Drinking Water Sources in Zhejiang Province*, the boundaries of administrative divisions and functional departments could be broken through the cross-regional collaborative legislation, and the imbalance between development and protection in the upstream and downstream areas of the watershed could be solved, promoting the collaborative development of the three regions and protecting the safety of drinking water sources.

It is suggested to establish an evaluation mechanism for upstream and downstream ecological compensation in the Yangtze River Basin and allow inter-provincial emission trading. The upper reaches of the basin should take responsibility for ecological and environmental protection while the lower reaches should compensate the efforts made by the upstream areas in improving and protecting the ecological environment and water sources. It is also necessary to strengthen the collaboration among the regions of the basin and insist on balancing the rights and responsibilities for ecological compensation. On the basis of the current incentive mechanism and in accordance with the pay principle of polluter, user, and beneficiary, economically developed downstream areas should compensate the upstream areas with less-developed economy. And the ecological compensation work with cross-regional and cross-system water supply is encouraged.

4.2 Developing a priority control list of emerging contaminants and collaboratively revising water quality standards

In 2017, Article 69 in the revised version of *Law of the People's Republic of China on Prevention and Control of Water Pollution* added some contents including "Investigating and assessing the pollution risks in drinking water sources, screening possible pollution risk factors, and taking corresponding measures to prevent risks",

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which provided legal guarantee for the prevention and control of trace contaminant complex pollution at source. Therefore, it is suggested to tackle scientific and technological problems at the national level, investigate the water quality analysis method of complex pollution and the comprehensive health effect evaluation method, establish the screening and identification technology of high-risk pollutants based on their health effects, and screen and develop the priority control list of emerging trace contaminants in large water sources in the upper, middle, and lower reaches of the Yangtze River.

Based on the priority control list of emerging contaminants, it is supposed to assess the group toxicity of pollutants and investigate their concentration limits. The assessment index could include detection rates, concentration levels, treatment effects of contaminants in DWTPs, and the necessity and feasibility of prioritizing the control of these pollutants. The concentration limits of priority contaminants could be determined by considering concentration limits of relevant pollutants set by domestic and foreign water quality standards and guidelines as well as the current efficiency of sewage and drinking water treatment processes in China. Meanwhile, the relevant parameters and their concentration limits in "Discharge standard of pollutants for municipal wastewater treatment plant" (GB 18918–2002), "Environmental quality standards for surface water" (GB 3838–2002), and "Standards for drinking water quality" (GB 5749–2006) could be updated and revised accordingly.

Considering that the characteristics of water pollution and the levels of drinking water treatment technology in different regions are different, local governments can cooperate with universities and research institutes that have relevant research experiences to formulate local drinking water quality standards according to actual situations in the region. For example, Shanghai issued the *Implementation Program of Water Pollution Prevention and Control Action Plan* in 2016, which explicitly proposed to strengthen the research and construction of the water environment standards system and promulgated the first local "Standards for drinking water quality" (DB 31/T1091–2018) in 2018. In the same year, Zhejiang Province promulgated a standard for the evaluation of modern water treatment plants in Zhejiang Province (version updated in 2018). In 2019, Jiangsu Province promulgated the first local standard for DWTPs at the provincial level, which was entitled "Standards of the key water quality parameters for urban water treatment plants in Jiangsu". These local standards not only meet the requirements in national standards, but also consider the planning and economic development of the Yangtze River Delta region and satisfy the urgent needs of people for high-quality drinking water. In the future, provinces and cities in the Yangtze River Delta should fully consider the water quality characteristics and water supply guarantee capacity of this region, and formulate regional standards to promote the joint allocation of water sources in the Yangtze River Delta, upgrade of water purification processes, and improvement in management level and drinking water quality.

4.3 Developing green treatment technology to further improve drinking water quality

The rapid social and economic development of China has brought unprecedented pressure to resource exploitation and ecological environment protection. The characteristics and degree of complex pollution in China's water sources are different from those in other developed countries. Thus, the experience of drinking water treatment technology in developed countries does not apply to us. Therefore, owing to the characteristics of different types of complex pollution in China' water sources and prominent problems concerning long water treatment processes, high energy consumption in operation and maintenance, and high doses of chemicals, we should center on ensuring that drinking water quality steadily meets national standards and improve the effectiveness of future water treatment systems from the perspectives of simplicity, cleanness, low energy consumption, and environmental protection. Developing green and efficient water treatment technologies is of significance, such as green physical separation technologies with high performance, anti-pollution property, and low energy consumption; safe disinfection technologies with a broad spectrum, low by-product formation, and continuous disinfection effects; and water treatment technologies based on new energy, materials, and concepts, so as to build urban drinking water treatment technology systems suitable for China's water quality characteristics and further enhance China's capabilities to ensure drinking water safety.

4.4 Innovating secondary water supply management mode and developing smart water-supply system

To solve the problem of secondary water supply, it is necessary to innovate the management mode. The difficulties of reforming the management mode are related to the ownership of secondary water supply facilities, costs of maintenance and upgrade, cooperation of residents, and personnel placement. To cope with the current problems of the secondary water supply facilities, including the diverse construction and management, unclear

regulatory duties, insufficient operation and maintenance responsibilities, and difficulties in raising the fund for device upgrade, the Ministry of Housing and Urban-Rural Development in conjunction with the National Development and Reform Commission, the Ministry of Public Security, and the former National Health and Family Planning Commission issued a *Notice on Strengthening and Improving the Construction and Management of Secondary Water Supply Facilities for Urban Residents to Ensure Water Quality and Safety*" (Jiancheng [2015] No. 31) in February 2015. Relevant departments should use management modes that adapt to region situations based on national and local regulations. Meanwhile, it is necessary to strengthen the professional training of secondary water supply management staff, and the staff in charge of water quality analysis and disinfection should obtain official qualifications. Besides, information disclosure is of significance, and multimedia platforms could be used to propagandize drinking water regulations, so that urban residents and relevant departments can jointly supervise and manage drinking water quality.

We should further pay attention to the research on secondary water supply facilities, tap water quality improvement technologies, on-line monitoring, remote monitoring, and automation technologies. In addition, we should fully exploit the advantages of information technologies in the Yangtze River Delta and deeply integrate artificial intelligence, big data, and Internet of Things to develop an intelligent Internet of Things for water supply and an online monitoring big data platform. In addition, experiences and practices that can be promoted would be formed through some urban pilot projects, thus ensuring the application of advanced technologies and providing scientific support for ensuring drinking water safety for urban residents.

5 Conclusion

Over the past decade, the drinking water safety guarantee work in China and the Yangtze River Delta has made significant achievements, and the drinking water quality has been effectively improved. However, people's requirements for drinking water safety and health are gradually increasing, and the drinking water safety guarantee work of the Yangtze River Delta mega-urban agglomeration still faces many challenges. In the future, as China's ecological environment protection continues to be strengthened, the quality of water sources will continue to improve and water treatment technologies will be developed in a greener and cleaner direction.

References

[1] State Councial of the PRC. Outline of the Regional Integration Development Plan of the Yangtze River Delta [M]. Beijing: People's Publishing House, 2019. Chinese.

[2] The NPC of the PRC. Document of the first plenary meeting of the law enforcement inspection group of the water pollution prevention and control law of the NPC Standing Committee [R]. Beijing: the NPC of the PRC, 2019. Chinese.

[3] Sun SN, Chen YN, Lin YJ, et al. Occurrence, spatial distribution, and seasonal variation of emerging trace organic pollutants in source water for Shanghai, China[J]. Science of the Total Environment, 2018, 639:1–7.

[4] Zhang RH, Wang FF, Fang C, et al. Occurrence of CX_3R-Type Disinfection Byproducts in Drinking Water Treatment Plants Using DON-Rich Source Water[J]. ACS ES&T Water, 2021 1 (3), 553–561.

[5] Fu, Q, Zheng, BH, Zhao, XR, et al. Ammonia pollution characteristics of centralized drinking water sources in China. Journal of Environmental Sciences, 2012, 24(10) 1739–1743.

[6] Lin ML, Qin JM, Zhang QB. Establishment and application of drinking water insurance technology system from water source to tap[J]. Journal of Environmental Engineering Technology, 2019, 9(4), 362–367. Chinese.

[7] Chu WH, Yang X, Zhou ZC, et al. Comprehensive solutions for three types of water sources in Taihu Lake basin based on the water quality characteristics: realizing the integrated control of typical and emerging pollutants[J]. Water Purification Technology, 2021(40), 6–11. Chinese.

[8] Shanghai Water Authority. Shanghai Water Supply Planning (2019-2035) [EB/OL]. （2019.07） [2022.09.01]. http://swj.sh.gov.cn/ghjhua/20200910/f1ad9739169a4804a9d6332704e147cc.html. Chinese.

[9] Water Special Office of the Ministry of Housing and Urban-Rural Development. Special Report on the National Major Science and Technology Project of China No. 1: Jiangsu Taihu Basin drinking water safety guarantee project has achieved remarkable achievement and promoted the development of urban water supply across the province [R]. Beijing: Water Special Office of the Ministry of Housing and Urban–Rural Development, 2019. Chinese.

[10] He Y M. Drinking water source quality safety and collaborative legislation on related substantial system in Yangtze River Delta Demonstration Area[J]. Environmental Pollution and Control, 2022,44(2):278–284. Chinese.

[11] Qu J H. Consideration of the main problems of drinking water quality in the China future [J]. Water & wastewater engineering, 2011,47(04):1–3. Chinese.

DOI 10.15302/J-SSCAE-2022.05.003

[12] Ike IA, Karanfil T, Cho J, et al. Oxidation byproducts from the degradation of dissolved organic matter by advanced oxidation processes-A critical review. Water Research, 2019(164):114929.

[13] Ding SK, Deng Y., Li HW, et al. Coagulation of Iodide-Containing Resorcinol Solution or Natural Waters with Ferric Chloride Can Produce Iodinated Coagulation Byproducts. Environmental Science and Technology, 2019(53), 12407-12415.

[14] Ministry of Water Resources of the People's Republic of China, "Water Security Plan for the Integrated Development of the Yangtze River Delta Region" was officially issued [EB/OL] (2021) [2021.7.7]. http://www.mwr.gov.cn/xw/sjzs/202107/t20210707_1527658.html. Chinese.

[15] Hou L A, Zhao H Y, Gao X. Green Development of the Safeguard for the Drinking Water Safety Driven by Innovation[J]. Journal of Engineering Studies, 2016(8):351–3. Chinese.