Discussion on Shanghai Water Treatment Plan

Jingwen Gao

College of geology and environment, Xi'an University of science & technology, Xi'an, China

*Corresponding author e-mail: 929158551@qq.com

Abstract. Water is one of the most important resources in production and life, and water pollution will break the ecological balance within water and thus threaten human life and production, and even human health. At present, water treatment methods and technology are attracting attention around the world. Shanghai is the earliest Chinese city to set up modern drainage facilities, which has accumulated rich and valuable experience in water treatment. Therefore, this study takes Shanghai as the research area, summarizes sewage treatment technologies used here, and analyzes the advantages and drawbacks of these technologies. It is hoped that this research can provide a theoretical basis for the sustainable development of China’s sewage treatment technology.

1. Introduction
Water is one of the most important resources in production and life. Although the total amount of fresh water resources in China is 2,800 billion cubic meters, the per capita value is quite low. Across the country, 18 provinces have a per capita water resources lower than the national average, eight of which are facing water shortage or even serious shortage. At a time when water shortage has hindered the harmonious development between man and nature, water pollution undoubtedly further worsens the shortage problem [1].

Urban water pollution mainly comes from the arbitrary discharge of urban domestic sewage and industrial wastewater, which affects the quality of surrounding rivers, reservoirs and groundwater [2]. Currently, the qualified rate of water sources in most cities in China is acceptable, with the southern area having a much better quality than the northern area. There are generally three types of water pollution, including urban pollution, industrial pollution, and agricultural pollution [3]. To be specific, urban pollution is caused by various domestic sewage, manure, garbage, etc. produced in urban life; industrial pollution results from industrial wastewater and sewage generated during industrial production; and agricultural pollution comes from organisms brought by ploughing, fertilization, and farming [4].

Water pollution will break the internal ecological balance of water, posing a threat to human life, production activities and even human health. Sewage discharge promotes the growth of pollution-tolerant aquatic organisms and leads to the decline of dissolved oxygen in water, thus causing water to become black and odor; the change of pH in water will affect the function of industrial equipment and thus destroy product quality; and polluted water does harm to human health through harmful substances enriched through organisms. [5]. When entering water, pollutants caused by humans will penetrate various layers under the hydrological cycle. For instance, activities such as mining, fossil fuel combustion, and automobile exhaust emissions worsen heavy metal pollution in surface water.
Concentrated in organisms through food chain, heavy metal pollutants affect the reproduction of aquatic organisms and then entry the human body through food chain, hand and mouth, and skin contact to endanger human health [6]. Therefore, in order to alleviate the increasingly severe water pollution and promote harmony between man and nature, countries around the world have paid great attention to water treatment methods and technologies.

2. Research Progress in Water Treatment at Home and Abroad

2.1. The Process and Basic Concepts of Water Treatment

Water treatment refers to the process of removing some harmful substances in the water which are unnecessary for production and life through physical, chemical and biological means (see Figure 1). The physical method refers to absorbing or blocking impurities in the water through the use of various filter materials with different pore sizes. While the adsorption method mainly relies on activated carbon, the blocking method improves water quality by using filters to block large-sized impurities. The chemical method uses various chemicals to convert impurities in water into substances that are less harmful to the human body or removes impurities by filtration [7]. Through the use of biology, especially organisms, biological treatment completes the decomposition of organics as well as the synthesis of organisms, and then converts organic pollutants into harmless gaseous products (CO2), liquid products (water) and solid products rich in organics (microbial population or biological sludge). Among them, unwanted biological sludge is separated from the purified water by solid-liquid separation in the sedimentation tank.

![Figure 1. The flow chart of water treatment.](image)

Urban sewage treatment mainly deals with chemical oxygen demand, biochemical oxygen demand, suspended substances, nitrogen, phosphorus, chroma, pH and Escherichia coli in water. The discharge standards of various pollutants in urban sewage treatment are shown in Table 1 (GB18918-2002).

| Serial Number | Item | Maximum allowable emission concentration of basic control items (daily average) unit: mg/l |
|---------------|------|-----------------------------------------------------------------------------------|
|               |      | First class standard | second class standard | third class standard |
|               |      | A characterization | B standard |     |     |     |
| 1             | chemical oxygen demand (COD) | 50 | 60 | 100 | 120 |
| 2             | biochemical oxygen demand (BOD) | 10 | 20 | 30 | 60 |
| 3             | suspended substance (SS) | 10 | 20 | 30 | 50 |
| 4             | total nitrogen | 15 | 20 | — | — |
| 5             | total phosphorus | 0.5 | 1 | 3 | 5 |
| 6             | ammonia nitrogen | 5 (8) | 8 (15) | 25 (30) | — |
| 7             | chroma | 30 | 30 | 40 | 50 |
| 8             | PH | — | — | 6-9 | — |
| 9             | total escherichia coli | 10 | 104 | 104 | — |

Table 1. Pollutant discharge standards for urban sewage treatment plants.
2.2. Introduction to Water Treatment Methods

Current water treatment methods include oxidation ditch method, stabilization pond method, AB process, hydrolysis-aerobic process, aeration method, A2/O method, SBR method, biofilm method, high pressure membrane method, etc. [8]. Among them, the hydrolysis-aerobic process is a complete technology formed by the Beijing Municipal Research Institute of Environmental Protection. With a focus on hydrolysis-aerobic technique, this technology includes hydrolysis-activated sludge treatment process, hydrolysis-oxidation ditch treatment process, hydrolysis-contact oxidation treatment process, hydrolysis-land treatment process and hydrolysis-oxidation pond treatment process. At present, hundreds of sewage treatment plants using this hydrolysis-aerobic process have been built throughout the country, such as Beijing Miyun Wastewater Treatment Plant, Shenzhen Shiyan River Wastewater Treatment Plant, and Xinjiang Changji Wastewater Treatment Plant. Meanwhile, due to its good capacity to resist organic loading shock, this technology can effectively remove impurities even under low temperature conditions and ensure stable amount of remaining sludge and water quality. Therefore, it is also suitable for sewage treatment in small towns in China.

2.3. Introduction to Water Treatment Processes

At present, water treatment processes are complex and involve various functions. The following takes typical sewage treatment plants in Xi’an as examples to introduce the commonly used water treatment processes and their applicable conditions.

2.3.1. Water Treatment at Beishiqiao. The Beishiqiao Wastewater Treatment Plant collects domestic sewage and industrial wastewater in the southern suburbs and southwestern suburbs of Xi’an for treatment. The wastewater has so high concentration of nitrogen and phosphorus content that it requires strict treatment effect. Therefore, the plant adopts a multi-stage process combining AAO, DE oxidation ditch and microbial flocculation filtration.

The advantage of this process lies in alternating nitrification and denitrification, which help completely separate the anoxic zone from the aerobic zone so that the sewage always enters from the anoxic zone. This way, a good denitrification effect can be maintained, and there is no need for a mixed liquid reflux system. However, the process takes up a large area for the treatment work; the oxidation ditch is shallow; and it requires heavy investment in equipment.

2.3.2. Water Treatment at Dengjia Village. The Dengjiacun Sewage Treatment Plant adopts a multi-stage process combining AO and coagulation filtration process, and gravity concentration and mechanical dehydration to deal with sludge and uses a CYY full process for deodorization.

The process has an edge in that the aerobic digestive solution directly enters the anoxic zone and there is no need to set a refluxing facility in the digestive juice, thus saving carbon sources. Compared with conventional processes, it requires smaller biological pool when the MLSS concentration is the same, increasing the sludge concentration but reducing the volume of the biological pool. However, the process takes up a large area for the treatment work; the oxidation ditch is shallow; and it requires heavy investment in equipment.

2.3.3. Water Treatment at Xi’an University of Science and Technology. The sewage treatment plant in Xi’an University of Science and Technology mainly collects and treats domestic sewage in the campus, which uses a combination of anaerobic, pre-denitrification tank and MBR membrane tank in treatment process supplemented by materialization.

The process has unique advantages in that the solid-liquid separation is efficient, the quality of water after treatment is excellent and stable, it requires only a small area for treatment and generates small amount of sludge, and the operation is convenient. However, there are some drawbacks. For example, the membrane module of the process requires heavy investment; the high-intensity aeration consumes too much energy; and regular replacement of the biofilm incurs large cost.
2.4. An Overview of Water Treatment in China

Written history of water treatment in China began with purifying water by alum; and Shanghai Yangpu Water Plant is an early relatively complete waterworks founded in 1882. Since the government is now attaching great importance to wastewater treatment, there has been increasing investment in this field (see Table 2) in recent years (Table 2) despite the fact that China started late in dealing with water pollution and still has no advanced technologies. By 2018, China has completed wastewater treatment investment projects worthing 172.75 billion yuan and achieved a daily sewage treatment capacity of 170.37 million cubic meters [9].

Besides introducing and learning from foreign technologies, China has also developed wastewater treatment methods that are suitable for local conditions, such as the hydrolysis-aerobic processes. China’s water treatment methods mainly adopt techniques such as neutralization, sedimentation, aeration, biological treatment, mixed dilution and filtration, which are aimed to meet the requirements of discharge standards and improve the treatment rate. Current treatment technologies used in China include blast aeration, oxidation ditch, AB process, SBR, biofilm and high-pressure membrane [10].

| Year   | 2013  | 2014  | 2015  | 2016  | 2017  |
|--------|-------|-------|-------|-------|-------|
| Money spent (a hundred million yuan) | 1055  | 1196.1| 1248.5| 1485.5| 1727.5|
| Proportion in GDP (%)              | 1.52  | 1.49  | 1.28  | 1.24  | 1.15  |

2.5. An Overview of Water Treatment Abroad

Since the 19th century, Western countries have undergone different levels of environmental pollution, leading to a decrease of dissolved oxygen in rivers and lakes, a drop or even extinction of aquatic organisms, and an increase in incidence of human diseases. In order to relieve the increasingly serious environmental problems, Western countries have strengthened investment in and support for sewage treatment. In the late 1990s, the urban sewage treatment rate in some developed countries reached more than 80%. At present, the United States has established urban sewage treatment facilities across the board, achieving a sewage treatment rate of about 100%, and a second-level sewage treatment standard [11].

In addition, Australian researchers have proposed the use of a new rotating bioelectrochemical contactor in the field of bio-power generation, which can increase the efficiency of rotating biological wastewater treatment technology that has been used in the sewage treatment industry for 30 years by 15%. Meanwhile, Australia has developed a technology that can handle high-concentration wastewater, whose cost is only one-tenth of that of the storage and chemical treatment and is currently considered to be the simplest, most convenient and economical processing technology.

3. An Overview of Shanghai—The Research Area

Located in the mouth of the Yangtze River, Shanghai is the leading city in the Yangtze River Economic Belt. It faces the Kyushu Island in Japan across the East China Sea, adjoins the Hangzhou Bay in the south, and connects Jiangsu and Zhejiang in the north and west respectively. As a large economy, Shanghai has had about 24.15 million permanent residents by the end of 2015, with a registered population of around 14.27 million (source: Shanghai Statistical Yearbook) [12]. It is a national central city, being China’s economic, transportation, science and technology, industry, finance, trade, exhibition and shipping center.

Shanghai is also the earliest city to build modern drainage facilities in China. The Shanghai Yangpu Water Plant founded in 1882 is the earliest and relatively complete modern waterworks in China; and the Eastern District sewage treatment plant built in 1927 is China’s first sewage treatment plant, which has provided valuable experience for domestic water treatment. Therefore, this paper takes Shanghai as the research object to explore the progress and direction of sewage treatment in China, which is of great practical significance.
4. Water Treatment in Shanghai

4.1. Urban Sewage Discharge
The centralized drinking water in Shanghai is all surface water, all of which comes from river sources. There are 4 municipal centralized drinking water sources in Shanghai, including the Yangtze River Qingcaosha Reservoir, Dongfengxisha Reservoir, Chenhang Reservoir and Huangpu River Kanazawa Reservoir. By 2017, the total annual wastewater discharge in Shanghai reached 2.12 billion tons, of which the total discharge of industrial wastewater accounted for 316 million tons; and the total discharge of chemical oxygen demand in wastewater was 141,800 tons, of which the total discharge of chemical oxygen demand in industrial wastewater accounted for 12,900 tons. On the whole, the city has 52 sewage treatment plants, having a sewage treatment capacity of 2637 million tons.

4.2. Water Treatment Methods Used in Shanghai
Currently, there are 52 sewage treatment plants in Shanghai, of which Bailonggang Wastewater Treatment Plant (with design scale of 2 million m³/d) is the largest wastewater treatment plant in Asia [13]. In recent years, Shanghai has achieved remarkable progress in wastewater treatment. For example, the Sitang Water Purification Plant adopts the A/O process, which discharges 21,000 tons of wastewater after UV disinfection into Yunzaobang every day; the Wusong water purification plant employs the A/O/O process to remove nitrogen and phosphorus and uses UV disinfection, with a daily treatment of 40,000 tons of domestic sewage meeting the standards; Taopu Industrial Zone sewage treatment plant uses catalytic reduction internal electrolysis and SBR treatment process, which stably processes 60,000 tons of industrial sewage on a daily basis. The following is a summary of the water treatment technologies currently used in Shanghai [14].

4.2.1. Oxidation Ditch. With a closed ditch structure, oxidation ditch combines the characteristics of the push-flow and fully-mixed activated sludge process, thus being able to complete aeration, sedimentation and sludge stabilization at the same time. Since the mixture of sewage and activated sludge continuously circulates, the system can form aerobic zone and anoxic zone separately, thereby realizing biological nitrogen and phosphorus removal. Wastewater enters the oxidation ditch and undergoes aeration during the day; and the oxidation ditch acts as a sedimentation tank at night. Compared with the activated sludge process, the oxidation ditch method has the advantages of simple treatment process and simple structure, greater sludge age, less residual sludge, easy dehydration, and stable treatment effect.

4.2.2. Stabilization Pond. Stabilization pond can effectively process domestic sewage and some organic industrial wastewater, which performs well in removing organics and pathogens. In particular, this method can be used as primary treatment, secondary treatment or even tertiary treatment in areas with warm climate and abundant sunshine.

4.2.3. AB Process. On the basis of the traditional two-stage method, the AB process further increases the sludge load of stage A (the first stage) to ensure an operation mode featuring high load and short sludge age. Its stage B is similar to the conventional activated sludge method with a low load and long sludge age. Due to the short sludge age and large volume, stage A performs well in removing phosphorus. Therefore, the volume of wastewater in B stage can be greatly reduced after the removal of numerous organics in stage A, and the low-load operation mode in stage B helps improve the water quality. However, the removal of organics in stage A leads to the loss of carbon source in stage B, so this process has no obvious advantages when dealing with low-concentration urban sewage.
4.2.4. Artificial Aeration. The dissolved oxygen in river is mainly derived from reaeration and the photosynthesis of aquatic plants, with the former being the main source of dissolved oxygen in water. However, it takes a long time for river to carry out self-purification by relying solely on natural reoxygenation. In contrast, artificial aeration mainly increases the oxygen content of water by the use of aeration and new revetment biological blankets, thereby efficiently reducing the pollution load of water and promoting the restoration of river ecosystems. Currently, artificial aeration includes fountain aeration and ecological revetment.

Fountain aeration enhances the exchange capacity between the upper and lower layers of water, which is beneficial to the aeration of water, the degradation of organics and the nitrification of ammonia and nitrogen. Besides, this method can achieve certain landscape effects at the same time.

In addition to beautifying the river bank and making the revetment ecologically clean, ecological revetment can also rapidly increase the dissolved oxygen in the water at the same time. This project has set up a layer of bio-carpet on the bank of the sample section with an area of 780 square meters. A water pump is arranged in the river channel to lift the polluted water to the top of the bank; and the water flows down the surface of the biological blanket disposed on the surface of the bank. Since the water layer is thin and flows downward, polluted water can be rapidly re-oxygenized. The indigenous microorganisms on the surface of the biological blanket decompose the organics that flow through the water, and ammonia nitrogen is oxidized to nitrate nitrogen. After a period of time, the algae which grows on the biological blanket will absorb the nitrogen and phosphorus nutrients flowing through the water. The technology can efficiently remove organics and ammonia nitrogen in the water with the fungi in the symbiotic system of bacteria and algae, thus avoiding black odor in the river or quickly clearing the black and odorous river channel, and relieving eutrophication.

4.2.5. Ecological Restoration. Ecological restoration refers to the stop of human disturbance to the ecosystem so as to reduce the load pressure or enable the ecosystem to evolve in an orderly direction relying on its self-regulation and self-organization. Besides, by using the self-recovery of the ecosystem and certain artificial measures, this technology can gradually restore damaged ecosystems or enable the ecosystems to develop in a virtuous circle. Since aquatic plants have a certain self-purification ability, a typical ecological restoration method is to regulate polluted environment and improve water quality by cultivating some aquatic plants possessing the ability to absorb pollution and purify environment, such as submerged plants and emergent plants.

5. Conclusion and Prospects

5.1. Shortcomings of Shanghai Water Treatment
In recent years, Shanghai has made remarkable achievements in water treatment despite some defects such as outdated facilities and equipment and inadequate processing facilities. At present, the urban drainage pipe network only covers few areas in Shanghai and the pipeline collection rate is quite low. Besides, sewage treatment plants there can only meet the standards in the process of water treatment and have no effective means for dealing with the sludge generated in sewage treatment, which is liable to cause second pollution to the environment. Furthermore, sewage equipment has the disadvantages of low efficiency, high energy consumption, high maintenance rate and low automation level.

5.2. Suggestions for Shanghai Water Treatment
As the first city in China to set up modern drainage facilities, Shanghai has accumulated rich and valuable experience in water treatment and is of great value to promote China’s wastewater treatment technologies. In order to improve the efficiency of urban sewage treatment facilities in Shanghai, it is necessary to control and standardize the mechanism, establish an administrative supervision system based on vertical management, and improve the legal and regulatory system based on the protection of public environmental rights. The specific suggestions are as follows.
To begin with, it is advisable to reduce and eliminate the amount of wastewater discharged from pollution sources. This can be achieved from four aspects, including the reform of production process to reduce the amount of wastewater discharge, good use of recycled water and recycled water systems, the control of the concentration of pollutants in wastewater as well as the recycling of useful products, and proper treatment of municipal waste and industrial waste.

Second, it is worthwhile to make comprehensive treatment planning and rational layout. This calls for efforts from five aspects. First, when formulating various plans, preventive measures should be taken for possible water pollution; second, comprehensive planning and management should be carried out to deal with water pollution sources; third, drainage standards should be well set to prevent arbitrary discharge of industrial wastewater and urban sewage; fourth, wastewater from the same industry should be processed in a centralized manner to reduce the number of pollution sources and facilitate management; fifth, well organized plans should be made to process contaminated water.

Third, it is necessary to strengthen supervision and management, and establish laws and control standards. On the one hand, environmental protection management agencies should be set up to coordinate and supervise the protection of water resources by various departments and factories. On the other hand, specific rules should be formulated to protect water, and control and manage water pollution.

References

[1] Yu Dongsheng & Ren Gaoxiang. Research progress of and countermeasure for the micro-polluted source water treatment technology [J]. Resources Economization & Environmental Protection, 2017 (8): 3-4.

[2] Yu Zhen. Research progress in water treatment technology [J]. Information Recording Materials, 2018 (6): 23-24.

[3] Zhang Shaofeng. Research on water treatment [J]. Petrochemical Industry Technology, 2018, v.25 (4): 92.

[4] Li Lun. On the application of aeration equipment in environmental engineering water treatment [J]. Low Carbon World, 2018 (1): 7-8.

[5] Zhu Zhenrong. Analysis of water treatment performance and membrane fouling of new ultrafiltration membrane [J]. New Technology & New Product of China, 2018(8):132-133.

[6] Wu Min & Dang Yuan. Environmental-friendly water treatment technology and its development trend [J]. Environment and Development, 2018, 30 (4): 111-112.

[7] Mou Jie. Application of ozone oxidation technology in water treatment. [J]. Environment and Development, 2018 (1).

[8] Zhang Lei, Liu Junxin, Zheng Tianlong & Guo Xuesong. Research progress of water treatment adsorbent preparation by sludge [J]. Industrial Water & Wastewater, 2018, 49(1):1-6.

[9] 2018 China Statistical Yearbook [M]. 2018. Beijing.

[10] Zhao Bingwen, Jiang Ping & Chen Xiaochun. Computational Fluid Dynamics Technique: Its Application to Water Treatment [J]. Environmental Science & Technology, 2006, 29(6):77-78.

[11] Xu Guoqing. Discussion on Improvement and Innovation of Shanghai Seawater Treatment Technology and Organization Structure [J]. Quality and Standardization, 2001(3):55-56.

[12] Shanghai Statistical Yearbook [M]. 2018. Shanghai.

[13] Lin Jiemei & Tang Jianguo. Shanghai sewage treatment practice and development countermeasures [J]. Water & Wastewater Engineering, 2010, 36 (1): 44-46.

[14] Mao Jie, Zhou Yanqin & Zhou Xiao Zhang Lei, Liu Junxin, Zheng Tianlong & Guo Xuesong. Research progress of water treatment adsorbent preparation by sludge [J]. Industrial Water & Wastewater, 2018, 49(1):1-6.

[15] Li. Impact of Source Water and Water Treatment Process on Drinking Water Quality in Shanghai [J]. Journal of Environmental & Occupational Medicine, 2013, 30 (12): 928-930.