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Effect of effluent from a sewage treatment plant in Shanghai on the slow flow of the Yangtze River

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ABSTRACT

In order to study the Shanghai sewage treatment plant after the DiBiao water effect on the quality of the Yangtze River Estuary, this paper in Yangtze Estuary collected water samples, including total nitrogen, petroleum, volatile phenol and mercury, 18 indexes and rebuilding DiBiao before receiving waters of the Changjiang Estuary water quality survey data contrast, analysis of water quality in receiving waters of the Changjiang Estuary sewage treatment plant effluent. The results show that the effluent of the sewage treatment plant after upgrading meets the discharge standard, with biochemical oxygen demand$_5$ of 2.03~2.73 mg/L and chemical oxygen demand of 5.25~11.25 mg/L. Besides, the other indexes in the receiving waters of the Yangtze River Estuary meet the standard of Class II except for total nitrogen, petroleum, mercury and volatile phenol.

Keywords: Effluent from sewage treatment plant; Class I pollutants; Water quality of Changjiang Estuary

1. Introduction

In recent years, with the continuous development of the social economy, urban water consumption has increased sharply, resulting in a large increase in wastewater discharge, urban sewage treatment plants to ensure the quality of water environment has played a significant role, but its effluent discharge into inland rivers or urban rivers, and intensified the pollution of the water environment. The mainstream of the Yangtze River flows through 11 provinces and autonomous regions and finally flows into the East China Sea at Shanghai. The Yangtze River not only provides these provinces with resources and conditions for economic development, but also receives effluent from many sewage treatment plants [1].

Data show that there are 29 sewage outlets along the Yangtze Estuary with a daily discharge volume of 300 m^3/d or an annual discharge volume of 100,000 m^3 or above. However, the receiving section of the Yangtze River also has its own ecological function, so the impact of sewage discharge on the water quality of the receiving water has attracted much attention. In this paper, the water quality of the receiving water in the Yangtze Estuary is taken as the research object to study the influence of effluent discharge after upgrading a sewage treatment plant in Shanghai. 18 water quality factors including basic control items [including chemical oxygen demand (COD), biochemical oxygen demand (BOD5)$_5$, ammonia nitrogen, total nitrogen, total phosphorus and petroleum], a class of pollutants (including mercury, cadmium, hexavalent chromium, arsenic and lead) and selected control items (including nickel, copper, zinc, benzo(a)pyrene, cyanide, sulfide and volatile phenol) were selected, and compared with the water quality survey data of the Yangtze Estuary before the upgrading and renovation of the sewage treatment plant in 2015, to evaluate the impact of the effluent discharge of the sewage

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treatment plant on the water quality of the receiving water, in order to provide scientific guidance for the effluent discharge control of the sewage treatment plant and the protection of the water environment of the Yangtze River.

2. Literature review

Liu [2] found that the total COD, ammonia nitrogen and total phosphorus emissions in the Yangtze River reach of Chizhou reached 18,811.2; 2,693.7 and 425.6 t/a, respectively. In 2018, the total annual discharge of industrial wastewater and mixed wastewater from 28 key sewage outlets in Yichang can reach 245 million tons; In the Yueyang section of the Yangtze River, the annual discharge volume of 8 sewage outlets into the river is 451 million m^3, and the total phosphorus is the most serious exceeding standard. Jing et al. [3] simulated the influence of effluent discharge from a sewage treatment plant in southern Jiangsu on tidal reach. When the accident discharge occurs, the influence range on the Yangtze River water body increases, and the pollutant concentration along with the river increases. Yang and Jia [4] conducted numerical simulation on the effluent discharge of two large sewage treatment plants in the urban area of Yangzhou and found that during the accidental discharge, the Grand Canal would be seriously polluted on the whole, and the 2.4 km water area along the banks of the Yangtze River would be affected, and the concentration and influence range of pollutants would increase. The water environment capacity of the Yangtze River is limited. When a large amount of sewage enters the Yangtze River, the water quality of the Yangtze River will be seriously affected. Data show that there are 29 sewage outlets with a daily discharge of 300 m^3/d or an annual discharge of 100,000 m^3 or more along the Yangtze Estuary, but the receiving section of the Yangtze River also has its own ecological function. In January 2016, General Secretary Xi Jinping pointed out at the symposium on promoting the development of the Yangtze River Economic Belt that the Yangtze River has a unique ecosystem and is an important ecological treasure house in China. At present and for a long time to come, the restoration of the ecological environment of the Yangtze River should be placed in an overwhelming position, and the protection of the Yangtze River should be emphasized instead of large-scale development. Therefore, it is a crucial and urgent problem to study the influence of effluent from sewage treatment plants on the water environment of the Yangtze River.

The innovation points of this paper are as follows: (1) Select the data before and after the upgrading of the sewage treatment plant for comparative analysis, so as to objectively compare the difference of the influence of effluent before and after the upgrading of the sewage treatment plant on the water quality of the receiving area; (2) 18 different types of indicators are selected to evaluate the change and impact of water quality, which is more comprehensive and accurate.

3. Materials and methods

3.1. Overview of a sewage treatment plant in Shanghai

The effluent is discharged into a sewage treatment plant in Shanghai in the Yangtze River Estuary, which mainly treats and accepts domestic sewage from towns and villages such as the west of Zhoupu City District and Huainan City District, and industrial wastewater from industrial parks such as an International Medical Park, Aircraft Assembly Base and Chemical Industrial Park, and also includes some landfill leachate. Among them, domestic sewage accounts for about 60%~70%, industrial wastewater accounts for about 30%~40%, landfill leachate accounts for about 1%, the design scale is 200,000 m^3/d. The designed influent water quality is 220 mg/L BOD_5, 500 mg/L COD, 35 mg/L ammonia nitrogen, 45 mg/L total nitrogen, 4 mg/L total phosphorus, etc., and the current inflow water fluctuates between 120,000 and 190,000 m^3/d.

3.2. Determination of monitoring range and station location

During the water quality monitoring of the Yangtze Estuary before the upgrading and renovation of sewage treatment plants in 2015, according to the Technical Regulations for Monitoring Land-based Outfall Outlet and Adjugating Sea Areas (HY/T 076-2005), stations 2 and 4~9 were set up according to the sector shape, with the outfall as the radiation center. The survey in 2015 monitoring stations, on the basis of considering the Changjiang River runoff and seawater intrusion cause along the shore of runoff, add the position 1 and position 3, at the same time is not affected by sewage treatment plant effluent area provide reference stance, stood a latitude and longitude (Table 1), to evaluate the sewage treatment plant effluent discharge effect on the quality of the Yangtze River Estuary [5].

3.3. Sample collection and analysis

In this study, water samples were collected from the effluent of the sewage treatment plant and 10 stations in the Yangtze River Estuary in March, June, September and December 2019. Since the water depth of monitoring stations in the Yangtze Estuary is between 5 and 20 m, stratified sampling is required in accordance with Technical Regulations for Estuary Ecological Monitoring (HY/T 085-2005). The stratified sampling in this study is shown in Table 2, of which three layers are collected at stations 1–3, 5, 6 and control

Table 1
Information table of station longitude and latitude

Position	Longitude	Latitude
Wastewater treatment plant outlet	121.878713	31.067435
Position1	121.8853361	31.10091389
Position2	121.8968556	31.07802778
Position3	121.9127	31.06418611
Position4	121.9015972	31.11396667
Position5	121.9222083	31.09288889
Position6	121.9496806	31.07708611
Position7	121.9212389	31.13183889
Position8	121.9486389	31.10935
Position9	121.976525	31.09406944
Contrast stance	121.9796056	31.14102222

Table 2
Layered sampling

Serial number	Water depth range of	Layer number
1	<10	Surface layer, 5, bottom layer
2	10~20	Surface layer, 5, 10, bottom layer

stations, and four layers are collected at stations 4 and 7–9. The collected water samples were placed in a clean brown glass bottle with a capacity of 1 L and taken back to the laboratory for storage in a refrigerator at 4°C.

The effluent standard of the sewage treatment plant shall comply with the water pollutant discharge standard of "Pollutant Discharge Standard for Urban Sewage Treatment Plant" (GB18918-2002), in which, the basic control items shall meet the first-class A standard, and the first-class pollutants and selective control items shall meet the standard value of the maximum allowable discharge concentration. According to the Water Environmental Function Zoning of Shanghai Municipality (2011 Revised Edition), the water quality of the Changjiang Estuary in the receiving area shall be subject to Class II standards in the Environmental Quality Standard for Surface Water (GB3838-2002).

3.4. Quality control and guarantee

In this study, all samples were determined by blank experiment and two parallel experiments, with a relative standard deviation range of 4%~9%. The detection data of each station were the average of the four quarters. Excel was used for data processing, ArcGIS was used for sampling diagram drawing, and Origin was used for other drawings [6,7].

3.5. Survey data before bid raising and transformation

Table 3 shows the water quality survey results of the receiving area before upgrading the sewage treatment plant.

4. Results and discussion

4.1. Basic control items

Oxygen-consuming pollutants are chemical substances that consume dissolved oxygen in water through biochemical action. When the amount of dissolved oxygen in water is excessive, a large amount of dissolved oxygen in the water will be consumed, thus affecting the normal activities of aquatic organisms. According to the content of oxygen consumption pollutants at different stations, no matter the effluent of sewage treatment plant (BOD_5 is 6.95 ± 0.96 mg/L, COD is 25.17 ± 4.53 mg/L) or the station in the Yangtze River Estuary (BOD_5 is 2.03~2.73 mg/L, COD is 5.25~11.25 mg/L), The indexes of oxygen consumption pollutants all meet the corresponding standards. Compared with the survey data on the water quality of the Yangtze River Estuary before the upgrading of the sewage treatment plant in 2015 (the average BOD_5 concentration was 2.81 ± 0.64 mg/L, and the average COD concentration was 15.46 ± 1.32 mg/L), the values were higher than the results of this survey. The results indicated that the water quality indicators of oxygen consumption pollutants in the Yangtze River Estuary not only met the corresponding standards, but also improved compared with the water quality in 2015. Therefore, after the upgrading of the sewage treatment plant, the oxygen-consuming pollutants in the effluent did not cause adverse effects on the water quality of the Changjiang Estuary.

Nutrient pollutants can cause eutrophication of water bodies, resulting in the mass reproduction of algae, changes in species and quantity of population, and destruction of the ecological balance of water bodies. Commonly used indicators include total phosphorus, ammonia nitrogen and total nitrogen.

In this study, the effluent of the sewage treatment plant (0.18 ± 0.03 mg/L) and the total phosphorus concentration of each station in the Yangtze Estuary (0.08~0.10 mg/L) met the standards. However, the survey results of water quality in the Yangtze River Estuary in 2015 showed that the average concentration of total phosphorus was 0.34 ± 0.06 mg/L. Since 2015, the total phosphorus concentration in the Yangtze River Estuary has been decreasing year by year, and the water quality index of total phosphorus has improved significantly and finally met the Class II standard,

Table 3
Water quality of receiving water body at effluent of sewage treatment plant in 2015 (mg/L)

Measurements	Concentration	Measurements	Concentration
COD	15.46 ± 1.32	BOD_5	2.81 ± 0.64
Ammonia nitrogen	0.78 ± 0.21	Total nitrogen	4.18 ± 0.56
Total phosphorus	4.18 ± 0.56	Petroleum	0.07 ± 0.01
Mercury	0.24 × 10–3 ± 0.32 × 10–5	Cadmium	ND
Hexavalent chromium	–	Arsenic	ND
Lead	ND	Nickel	–
Copper	0.002	Zinc	0.06
Cyanide	–	Sulfide	–
Benzo(a)pyrene	–	Volatile phenol	0.0006

Note: "–" indicates unmonitored data.

indicating that the effluent discharge has no impact on the total phosphorus index in the affected area.

Ammonia nitrogen in the effluent of the sewage treatment plant (1.44 ± 0.34 mg/L) and the Yangtze Estuary water station (0.15~0.32 mg/L) meet the standards (but the total nitrogen only in the effluent of the sewage treatment plant (8.92 ± 1.70 mg/L) meet the standards. However, in the affected area (1.14~2.86 mg/L) and the control station (2.46 ± 0.74 mg/L) of the Yangtze River Estuary, it exceeded the standard of Class II. The results of the water quality survey of the Yangtze Estuary in 2015 showed that the average concentration of ammonia nitrogen was 0.78 ± 0.21 mg/L, and the average concentration of total nitrogen was 4.18 ± 0.56 mg/L. Compared with 2015, the water quality indexes of ammonia nitrogen and total nitrogen monitored this time in the Yangtze Estuary were significantly improved, but the total nitrogen index still did not meet the Class II standard. Further tracing of the source is required [8,9].

Petroleum is a mixture of various hydrocarbons, which is the most common and serious pollution of water bodies such as oceans and rivers. Petroleum dispersed in water bodies is often oxidized and decomposed by microorganisms, which consumes dissolved oxygen in the water and deteriorates water bodies. In this study, the concentration of petroleum in the effluent of the sewage treatment plant (0.13 ± 0.05 mg/L) met the discharge standard. However, some stations (2, 3, 5, 6 and 9 stations) and control stations (0.06 ± 0.01 mg/L) in the affected area (0.04–0.08 mg/L) in the Yangtze Estuary exceeded the Class II standard (Fig. 1) and were basically equivalent to the oil concentration detected before upgrading (0.07 ± 0.01 mg/L). It indicates that there may be other long-term pollution sources in excess of petroleum concentration.

4.2. Class of pollutants

Class I pollutants are the pollutants that can accumulate in the environment or animals and plants and have long-term adverse effects on human health. It is not only the world recognized toxic carcinogens, but also the object of strict control in the process of environmental protection in China. Among the pollutants studied in this paper, lead and cadmium met the standards at the effluent of sewage treatment plants, but were not detected in the Yangtze Estuary throughout the year. Hexavalent chromium and arsenic all meet the standards at each station. Although mercury ($0.18 \times 10^{-3} \pm 0.84 \times 10^{-5}$ mg/L) in the effluent of sewage treatment plants meets the discharge standard, However, the concentration of both the stations (1.16×10^{-3}~1.77×10^{-3} mg/L) and the control stations ($2.01 \times 10^{-3} \pm 1.94 \times 10^{-5}$ mg/L) in the affected area exceeded the Class II water quality standard (Fig. 2), especially the concentration of the control points not affected by the effluent discharge of sewage treatment plants was higher. This indicates that the background value of mercury concentration in the region is high or there may be other sources. Studies have shown that the discharge of oil-bearing wastewater, oil spills and industrial wastewater from large ships in the course of transit may cause mercury pollution in water

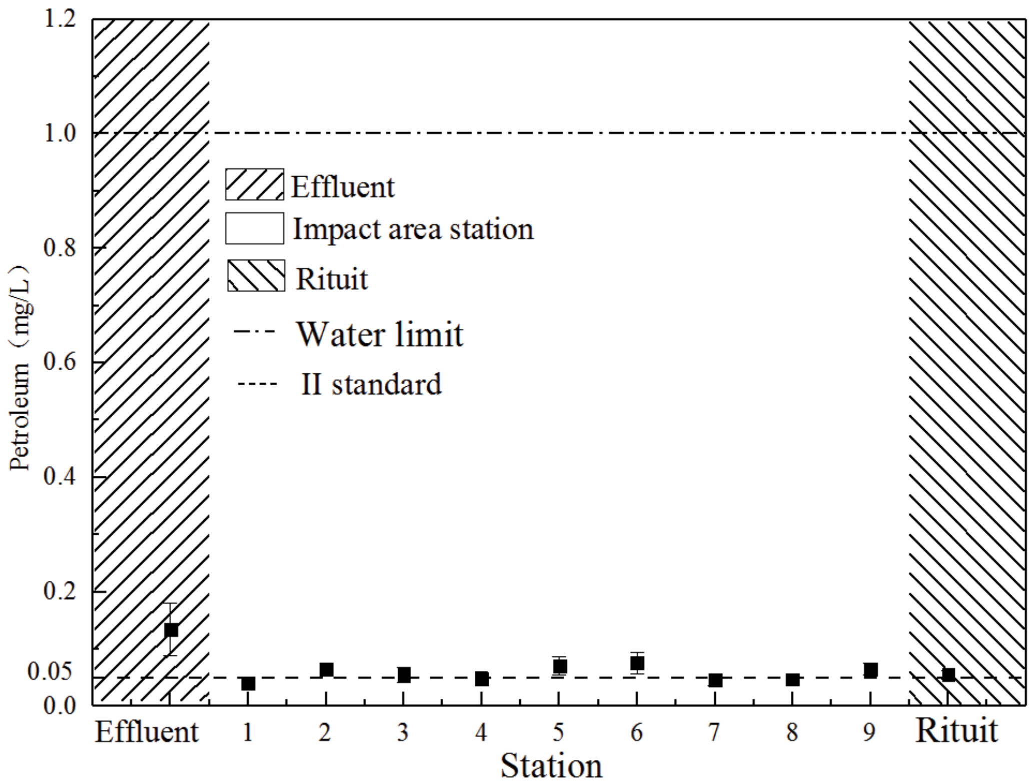

Fig. 1. Oil content at different stations.

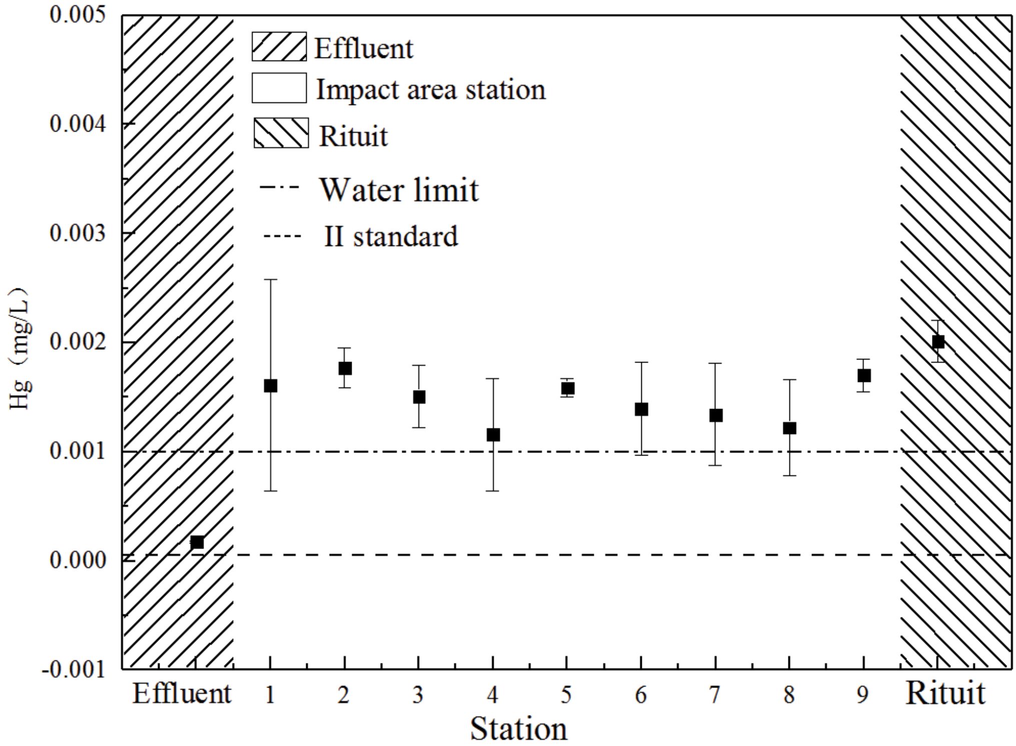

Fig. 2. Mercury content at different stations.

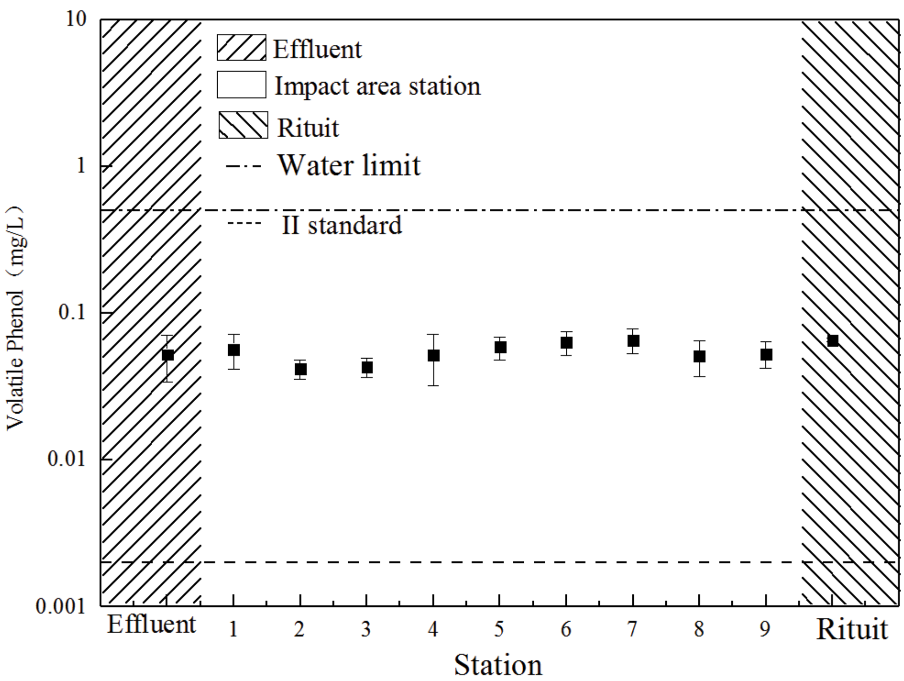

Fig. 3. Volatile phenol content at different stations.

bodies. In this study, the affected area of the Yangtze River Estuary is located in a frequent shipping area, and there are Laogang industrial areas and landfill sites around it, which may cause serious mercury pollution [10].

4.3. Select control items

The selected control items are mainly the pollutants that have a long-term impact on the environment or are more toxic, or the toxic and harmful chemicals and trace organic pollutants that affect biological treatment and are not easy to be removed in urban sewage treatment plants. Benzo(a)pyrene was not detected in the effluent of sewage treatment plants and the Yangtze Estuary all year round in the selected control projects studied in this paper. Copper and nickel meet the discharge standards at the outlet, but have not been detected in the Yangtze River Estuary all year round; cyanide, sulfide and zinc all met the standard at each station; The volatile phenol in the effluent water (0.052 ± 0.018 mg/L) met the discharge standard, but in the affected area stations (0.042~0.066 mg/L) and the control stations (0.066 ± 0.002 mg/L) greatly exceeded the standard of Class II (Fig. 3). The results of this study were about 1–2 orders of magnitude higher than that of 2015, indicating that the Yangtze River Estuary may have been seriously polluted by volatile phenol during 2015–2019 [11–17].

5. Conclusions

To sum up, the effluent of the sewage treatment plant upgraded and reformed in this study all met the discharge standards. In the receiving waters of the Yangtze River Estuary, all the other indexes except total nitrogen, petroleum, mercury and volatile phenol met the Class II standards. Compared with the water quality in the affected areas of the Yangtze River Estuary before the upgrading and reconstruction in 2015, the water quality of this time was generally improved, but the mercury and volatile phenol indexes still deteriorated. Therefore, China should actively strengthen the monitoring of mercury and volatile phenol in the Changjiang Estuary, and formulate a systematic monitoring plan to prevent its continuous deterioration and protect the ecological environment in the Changjiang Estuary.

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