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RESEARCH ARTICLE

Status of water environment pollution in the Xixi Wetland and its ecological treatment countermeasures

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Abstract In this paper, the water quality of the Xixi Wetland was evaluated and the characteristics of water pollution were described according to the survey data. Based on the status of water quality and its functional requirements as an urban wetland, biological-ecological countermeasures were suggested. The experimental use of ecological technologies, such as artificial wetlands, ecological aquiculture and artificial floating island, were done in several fish ponds in the Xixi Wetland. Water monitoring results show that the quality of the treated water has improved significantly and the measures to purify the eutrophic water in the wetland have been effective.

Keywords water environment pollution, ecological treatment, eutrophication, Xixi Wetland

1 Introduction

The Xixi Wetland, as a green "kidney" of Hangzhou City, is located in the west of the city. Covering an area of 10.08 km^2 (Gao, 2006), it consists of natural low-lying wetland with villages concentrated in the middle and scattered houses and forests. It is one of the suburban wetlands, which are rare in China and even in the world. However, the area of the wetland has continuously been decreased due to anthropogenic activities in production and living, and the city land has expanded in the last 1000 years, resulting in functional degradation and local environmental degeneration of the wetland. Therefore, it is urgent to protect the Xixi Wetland and to renew its ecology.

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2 Current situation and the main problems of water resource

An ancient poet once said that water was the soul of the Xixi Wetland. Presently, water is not only the soul and life line of the wetland, but also the basic element of its ecological reconversion and reconstruction, the precondition of improving the ecological quality, and the key to sustainable utilization of tourism development. However, the problem of eutrophication of its water body is serious. If no measures are taken to deal with the polluted water, it will incur adverse effects on the ecology of the protected wetland region. The solution of this problem is the key to protect and develop the Xixi Wetland.

2.1 General state of the water resource

The Xixi water web belongs to the water system of the Beijing-Hangzhou Canal. The main rivers of the Xixi Wetland are the Xixi River and Yanjiagang River flowing from the west to the east, and the Wuchanggang River, the Jiangcungang River and the Zijinggang River flowing from the south to the north. All these rivers join together to flow into the Yuhangtang River in the north. The net water density of the Xixi Wetland reaches up to 25 km/km^2, consisted of crossed rivers and more than 11000 ponds, with a total water area about 50% and a total length of rivers of about 100 km. The total amount of surface water is about 5 million m^3 and the superficial underground water is also abundant in the Xixi Wetland. Thus, the Xixi Wetland shows the typical characteristics of both a water town in south China and a wetland.

2.2 Evaluation of the characteristics of water environment pollution

During the past decades, the quality of water environment in the Xixi Wetland dropped greatly along with the

development of industry, commerce, crop farming and breeding and the lack of a consummate establishment to cut off sewerage influx. Industrial and domestic wastewater and the leaching of pollution sources from farming and breeding industry discharged directly into the water body have led to serious eutrophication of the Xixi Wetland water causing low dissolved oxygen (DO), high chemical oxygen demand (COD_{Mn}) and high nonionic nitrogen content. Subsequently, the water self-purification and renewal capacity has become very poor and the Xixi Wetland functions have degenerated greatly. According to the survey results of the water quality in 2004 by the Environmental Science Research and Design Institute of Zhejiang Province, the water body in the Xixi Wetland was badly polluted. In every tested section of the water body, there were some water quality indices that failed to meet up with the standards of type V water [1]. Among sections of the water bodies tested, the water with the best quality was found in the Qiuxuean and Chaotianmo ports, and the worst was found upriver of the Yanshan River and downriver of the Yuhangtang River with quality below the type V standard. With regard to water quality indices, those not reaching the standards were mainly related to the content of petroleum, total phosphorus (TP), total nitrogen (TN) and NH_3-N (Fig. 1) resulting from the pollution from daily life, farming, breeding industry and river navigation.

In order to investigate the pollution situation of the water environment in the Xixi Wetland with time, a water survey was conducted again in July, 2006 in the upriver and downriver areas of the main rivers and typical ponds in the protected region (Table 1). Compared with the survey results in 2004, water quality has improved because comprehensive treatment measures had been taken, including migration of local farmers and construction of pipes to control wastewater. However, the problem of water eutrophication still exists. According to the survey results, the water was polluted mainly with organic pollutants, such as NH_3-N, TP and TN contents, which were much higher than the type V standard, and the biochemical oxygen demand (BOD_5), COD_{Mn} were also higher in different degrees. This shows that there is still a big gap from the type III water [1] set by the local government in the development plan.

3 Countermeasures to prevent and treat the polluted water body

To treat the polluted water body in the Xixi Wetland thoroughly, comprehensive measures should be taken,

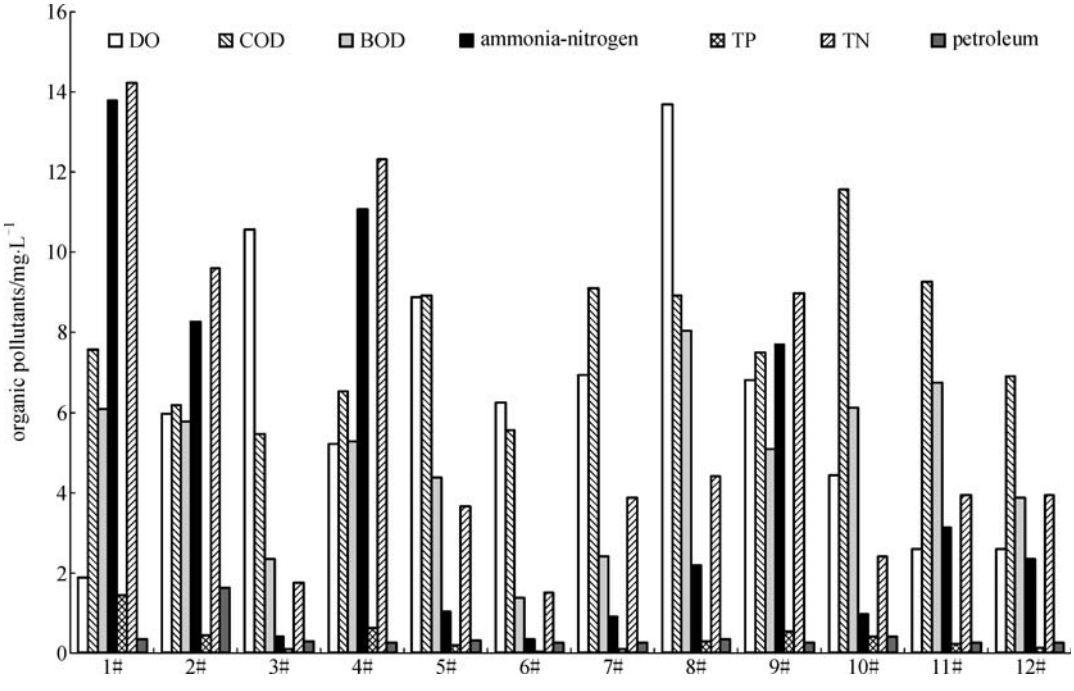

Fig. 1 Results of water quality survey in the Xixi Wetland in 2004. 1# and 2#: the Yanshan River; 3#: the Qiuxuean Port; 4#: the Wuchang Port; 5# and 8#: the Jiangcun Port; 6#: the Chaotian Port; 7#: the Yanjia Port; 9# and 10#: fish ponds; 11# and 12#: the Yuhangtang River.

1) According to the Environmental Quality Standard of Surface Water (GB3838-88) in China, water quality indices (unit:mg·L^{-1}) of the type III are DO ≥ 5, COD_{Mn} ≤ 6, BOD_5 ≤ 4, TN ≤ 1, TP ≤ 0.1 (0.05 for lakes or reservoirs), NH_3-N ≤ 1.0; water quality indices of the type IV are DO ≥ 3, COD_{Mn} ≤ 8, BOD_5 ≤ 6, TN ≤ 2, TP ≤ 0.2, NH_3-N ≤ 1.5; water quality indices of the type V are DO ≥ 2, COD_{Mn} ≤ 10, BOD_5 ≤ 10, TN ≤ 2, TP ≤ 0.2, NH_3-N ≤ 2.0.

Table 1 Results of water quality survey in the Xixi Wetland in July, 2006 unit: $mg \cdot L^{-1}$

site	DO	COD_{Mn}	BOD_5	NH_3-N	TP	TN
1#	6.22	6.60	4.53	3.92	0.35	3.73
2#	5.07	6.46	2.80	1.00	0.20	1.25
3#	4.52	8.40	4.60	2.76	0.25	3.45
4#	6.02	6.26	3.68	2.43	0.48	2.87

1#: the Yanshan River; 2#: the Jiangcun port; 3# and 4# : fish ponds. DO: dissolved oxygen; COD_{Mn}: chemical oxygen demand; BOD_5: biochemical oxygen demand; TP: total phosphorus; TN: total nitrogen.

such as measures to enhance the facilities to discharge, store and treat the wastewater, and to establish corresponding laws and strengthen propaganda, education, supervision and management. In addition, biological-ecological remedial technologies should be used based on the ecological theories to improve the self-purification capability of the water body and to accelerate the process of ecological restoration and wetland construction. In this way, the polluted water environment will be treated ultimately and thus, the Xixi Wetland will play its ecological service roles for Hangzhou city (Wang and Lu, 2007).

3.1 Biological-ecological remedy technologies

Biological-ecological remedy technologies take advantage of the metabolism process of plants and its symbiotic microorganism to translocate, transform and degrade the pollutants, and thus, to remove the pollutants from the water (Dong et al., 2002). These technologies include biofilm treatment technology, constructed wetland treatment technology, artificial land treatment technology and ecological floating island technology and so on (Ma et al., 2006). Based on the environmental situation, hydrological factors and features of water pollution in the Xixi Wetland, technologies such as artificial wetland, ecological floating island and sustainable aquiculture were mainly suggested for comprehensive and effective treatment of the polluted water.

3.1.1 Treatment technology of constructed wetland

It is effective in treating wastewater with the advantages of low cost in construction and maintenance, high quality of effluent water, low demand for technical operation (Knight et al., 2000; Du, 2007; Wei et al., 2005), as well as aesthetic pleasure. Reconstruction and flow adjustment of existing ponds can be used to treat surface resource pollution, especially for the water used in aquiculture. Then, native plants of aesthetic value or forage use are grown on the top. Based on demands, the landscape effect can be produced by using ornamental plants, forage plants for fish, or even native plants for biodiversity protection.

3.1.2 Ecological aquiculture

Ecological aquiculture is the definite trend in fishery and it plays an important role in preventing and treating fish diseases, improving the qualities of aquatic production, and purifying water in the fish pond (Zhao et al., 2004; Miao and Jiang, 2007; Shen et al., 2005). Some aquatic organisms are suggested to be stocked in an integrated poly-culture mode with an appropriate density in a closed water environment, such as local filter-feeding fish, zoobenthos-feeding fish, and mollusk like clams and snails fed on the organic crumb and microorganisms. Such a way of aquaculture is helpful for keeping the water ecological balance and purifying the water body.

3.1.3 Artificial ecological floating island

Due to its various functions such as purifying water, providing living space for organisms, landscaping and eliminating waves, artificial ecological floating island is widely applied in reservoirs with fluctuating water levels or other lakes where macrophyte cannot grow on the bank. It is also constructed in closed water areas like ponds with aesthetic purposes (Fang et al., 2004; Nakamura et al., 1995). It is suggested to construct floating islands planted with vegetables and flowers in ponds and ports in the Xixi Wetland, for the purpose of water cleaning and landscaping.

3.2 Application of the ecological treatment technologies to the water body and their effectiveness

To check for the effectiveness of the biological-ecological remedy technologies on purifying water, four fish ponds with a total area of 12414.1 m^2 at the northwest side and one at the southeast side of the Wanglu Bridge in the Xixi Wetland have been selected as the test demonstration areas of ecological treatments and the control since January, 2007. After the construction to connect the ponds and enhance afforestation along the bank was finished, the following technologies were used for the biological-ecological purification treatment: 1) ecological aquiculture: stocking variegated carp (*Hypophthalmichthys molitrix*), silver carp (*Hypophthalmichthys molitrix*), Snail (*Cipangopaludina chinensis Gray*), mussels (*Anodonta woodiana*), shrimp (*Macrobrachium nipponensis*); 2) artificial floating island: constructing a floating island with PVC frames, with a total area of 500 m^2 and planting vegetables with high entertainment and flower plants; 3) artificial wetland: construction of an artificial wetland of 490 m^2 with bagged zeolite as the first layer of stuffing and cinder as the second layer, and planting *Phragmites australis* on the top. After all the constructions were completed and put into use, the water quality was tested every 15 days since July 17. The monitoring results show that water quality in

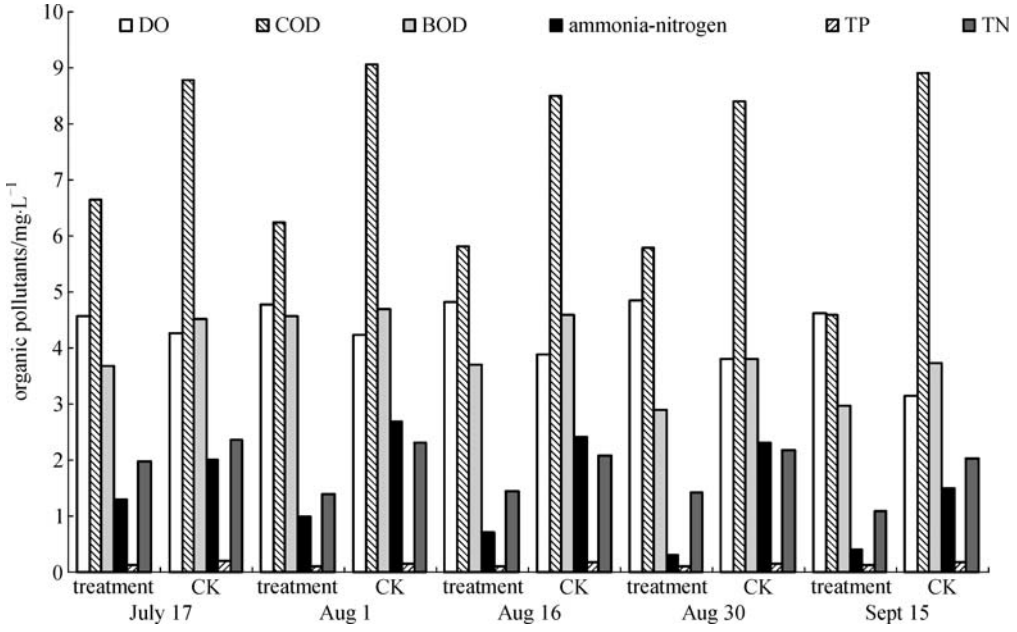

Fig. 2 Results of periodical monitoring of water in the project ponds in the Xixi Wetland in 2007. CK: control.

the treated ponds was improved to a certain degree compared with that of the control, and the improvement became more and more obvious with time. Meanwhile, we also observed a slight improvement of water quality in the control ponds, but the purifying process was very slow and pollution recurred frequently, and most of test indices indicated the water still belonged to type IV to V water. On the contrary, although fluctuations in some water quality indices were found such as temperature change and sampling operation, the treated water shows a trend of being cleaner according to most of the tested indices which improved significantly, especially COD_{Mn}, BOD_5 and NH_3-N content, which were in accordance with the standard of type II to III water. The quality of treated water has reached the standard of type I based on the BOD_5 index of the last two water samplings on August 30 and September 15 (Fig. 2), indicating that the biological-ecological measures worked well and had a distinct effect on purifying water body in the fish ponds.

4 Concluding remarks

The water environment in the Xixi Wetland has improved since water protective measures were taken and renovation projects were implemented. However, much work is still needed due to the serious water pollution. Only by way of protection and natural renewal of the ecological system will it be possible to reach the demand and target for reconstructing the ecological system of the degenerating lake land in the Xixi Wetland. Based on the results of the water survey, we proposed integrated countermeasures and employed several biological-ecological remedy technologies in the typical fish ponds in the Xixi Wetland to improve the water purifying process. The indices of the treated water have greatly improved. With considerable economic achievement in aquatic production and effects of improved water environment, the proposed biological-ecological remedy technologies are worthy of application in a more extensive way to get better ecological, social and economic benefits at the same time.

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