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RESEARCH ARTICLE

Eutrophication status and control strategy of Taihu Lake

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Abstract The water quality and eutrophication status of Taihu Lake in recent years are presented and the pollution trends are analyzed. It is shown that because of unreasonable industrial structures, pollution discharge per GDP is high within the Taihu basin, and the pollution discharge from point and non-point sources exceed the basin's environmental carrying capacity. Especially, excessive pollutants containing nitrogen and phosphorus are being discharged. Moreover, eutrophication may also result from internal pollution sources such as the release of nutrient elements from sediment. All these factors have resulted in the water quality deterioration of Taihu Lake. To solve this environmental problem, possible control strategies are summarized, including the control of internal pollution sources and inflow-river pollution, ecological restoration and reconstruction of the degraded lakeside zone ecosystem, clean water diversion, dredging, and manual algae removal.

Keywords Taihu Lake, eutrophication, control strategy

1 Introduction

The increased nutrients and amounts of chemicals in a eutrophicated ecosystem is often a result of human activity. Eutrophication is an increasingly important water environmental issue and has caused widespread concern globally in recent years. The issue surfaced as early as the twentieth century, when the appearance of eutrophication in lakes already attracted people's attention in America and in some European countries. Over the last 40 years, numerous investigations and practices have been performed to abate this growing problem. Treatment of eutrophication has also been carried out in China although the effect is not significant. When eutrophication occurs, phytoplankton grows rapidly, causing water quality deterioration and water function decline. This leads to the widespread death of a range of aquatic organisms, restricting utilization of lake resources. The negative effects of eutrophication also extend to the areas of sustainable economic development and human health [1–3].

Taihu Lake is the third largest freshwater lake in China, with a surface area of approximately 2,338 km^2 and an average depth of 1.89 m. The annual average quantity of water input into the lake is 7.66×10^9 m^3, and the residence period of Taihu Lake is about 300 days. There are over 300 inflow-rivers and outflow-rivers around Taihu Lake, among which 60% of these rivers are inflow-rivers. As the core area of the Yangtze Delta, the water resource of Taihu Lake has multiple functions, such as for drinking, industrial and agricultural utilization, shipping, tourism, basin flood control, and water storage. Naturally, the Taihu basin is an economically developed district with convenient transportation. It has only 3% of the total population in China, yet the GDP in this area accounts for 12% of China's total GDP. As a result, the GDP per capita is much as 3.5 times as the state average. However, water quality of the Taihu basin has declined and eutrophication has become worse in recent years. The area of Taihu lake that is affected by harmful algal blooms is continuously increasing. Algal blooms mainly occurred in Meiliang Bay, Zhushan Bay, and a part of the Western Lake before 2000, which together make up approximately 50% of the total lake area. By 2007, however, they extended to the whole western part of the lake, involving more than half of the lake area [4]. Moreover, algal blooms were observed more and more frequently, and the duration of blooming also became longer. Eutrophication has already seriously affected industrial and agricultural development and has threatened drinking water security at the Taihu basin [5]. This paper presents an analysis of the status and developing trends of water quality and eutrophication of Taihu Lake. The causes for eutrophication are explored and future control strategies are also proposed.

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2 Water quality and eutrophication state of Taihu Lake

2.1 Taihu Lake water quality profile

Taihu Lake comprises five districts: Wuli Lake, Meiliang Lake, West Shore Area, Lake Center, and East Shore Area. East Shore Area has the best water quality among the 5 districts, followed in order by Lake Center, West Shore Area, Meiliang Lake, and Wuli Lake. At Taihu Lake in 2007, the permanganate index (PI), total phosphate (TP), and total nitrogen (TN) were ranked Grade III (between 4 mg/L and 6 mg/L), Grade V (between 0.1 mg/L and 0.2 mg/L), and worse than Grade V (lower than 2.0 mg/L) on Surface Water Environmental Quality tests, respectively. Compared with the situation in 2005 and 2006, there was no significant improvement in 2007, and TP pollution became even worse, wherein the contamination level increased from Grade IV (between 0.05 mg/L and 0.1 mg/L) to Grade V (between 0.1 mg/L and 0.2 mg/L).

2.2 Variation tendency of comprehensive trophic level index (TLIc)

TLIc was adopted to evaluate the Taihu Lake eutrophication status from 1994 to 2007. PI, TP, TN, Chla (chlorophyll a), and WT (water transparency) were chosen to calculate for TLIc. The TLIc variation tendency is shown in Fig. 1. Taihu Lake has been basically in the status of eutrophication since 1994, and its nutrition level has exhibited only slight fluctuations during the past ten years. However, the degree of eutrophication of Taihu Lake has increased recently and has reached the medium eutrophication level. The mean value of TLIc in 2007 was 61.35, close to the lower limit of medium eutrophication. On the other hand, TLIc changed by month in 2007 and the peak value appeared in May and June (Fig. 2). The maximum of 67.12 was found in June. Correspondingly, as shown in Fig. 3, Chla concentration dramatically increased in May and June, and the maximum value was obtained in June, which contributed to the increase in TLIc.

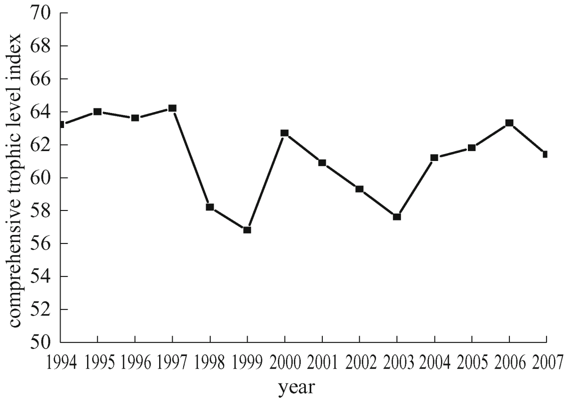


Fig. 1 Trend of index of eutrophication of each month in 2007

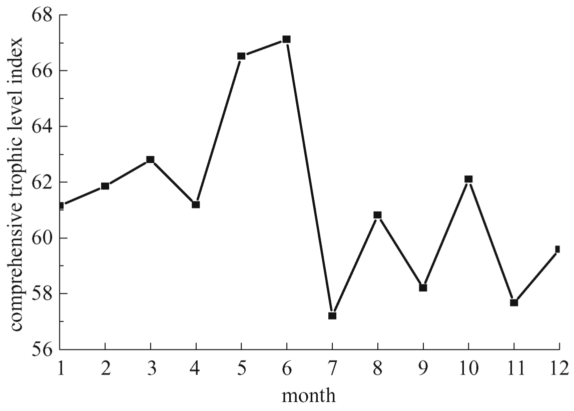


Fig. 2 Average comprehensive trophic level index (TLIc) of Taihu Lake

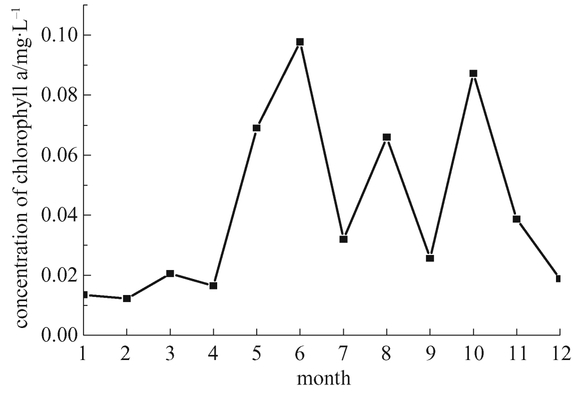


Fig. 3 Trend of concentration of chlorophyll a of Taihu Lake in 2007

2.3 Variation tendency of major eutrophication indexes

Water quality of Taihu Lake deteriorated and PI increased considerably in the ninth five-year period, but both PI and TP decreased in the tenth five-year period and somehow increased again after 2003 (Fig. 4). In contrast, TN increased in the early phase of the tenth five-year period and the pollution level stayed steady afterwards. Compared with the pollution level at the end of 2000, PI and TP were reduced but TN increased in 2005. Such a trend has been maintained from 2006 and 2007. PI and TN have been reduced to some degree, but TP has continuously increased. Figure 5 shows that the water quality of Meiliang Bay has been worse than Grade V since 2000.

2.4 Algal bloom of Taihu Lake

Algal blooms have been occurring frequently in the northern area of Taihu Lake recently. According to environmental monitoring data from the Shazhu monitoring site in Gonghu, the maximum algal densities of 2004,

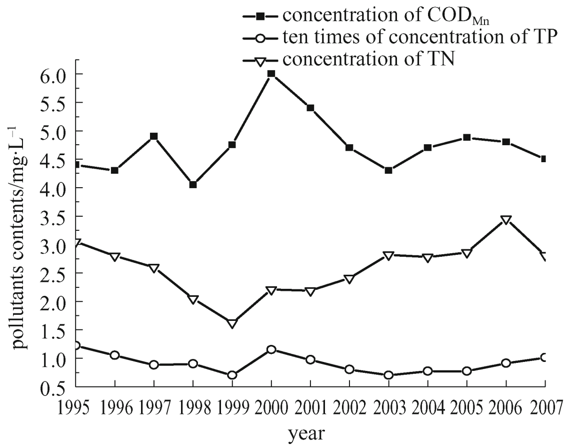


Fig. 4 Trends of three main water quality indexes of the Lake

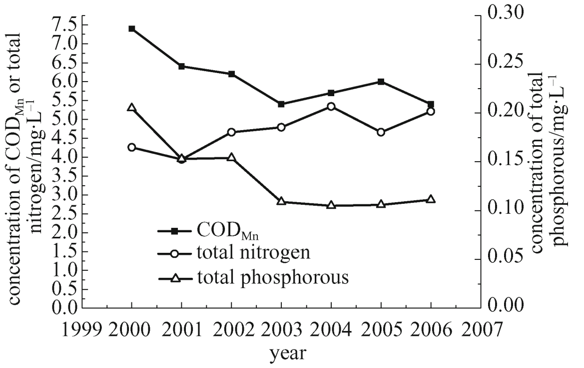


Fig. 5 Trends of concentration of main pollutants of Meiliang Bay

2005, 2006, and 2007, which reflect the degree of algal bloom, were 122, 25.3, 77.1, and 77.1 million cells per liter, respectively. Generally, algal bloom often occurs after June every year, but in 2007 blue algal breakout was observed one month ahead of that. In April and May 2007, the area of algal bloom amounted to 760 km^2, accounting for one third of the total lake area. Moreover, algal density on May 28th 2007 at the Shazhu monitoring site was detected to be 5.57×10^7 cells per liter, which was much higher than the maximum of the corresponding period in previous years. Clearly, it should be noted that under proper hydrographical and meteorological conditions, such as high temperature, intense light, suitable wind speed and wind vane, the area of algal bloom might further increase, worsening the current pollution status.

3 Reasons for Taihu Lake eutrophication

3.1 High discharge of pollutants per unit area and unreasonable industrial structures

With the rapid development of industry, the GDP and industrial production value of the Taihu basin considerably increased during the ninth and tenth five-year periods (Figs. 6 and 7). It can be seen from the graph that GDP had quadrupled from 1995 to 2005 and industrial production value had increased more than fourfold from 1999 to 2005. The population had grown year after year (Fig. 8), causing direct increases in pollution discharge. 1.405×10^5 hectares of cultivated area were lost between 1995 and 2005 (Fig. 9). In addition, the proportion of the secondary and tertiary industries in Suzhou, Wuxi, and Changzhou increased (Fig. 10).

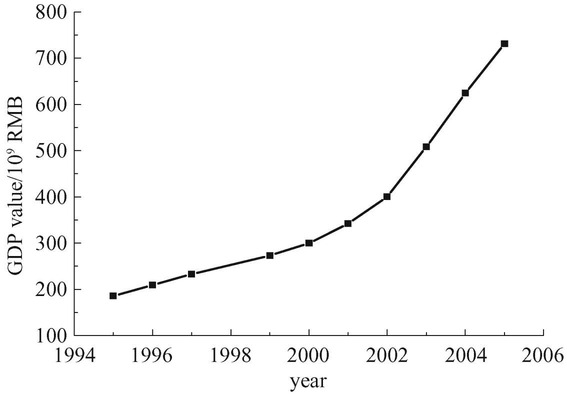


Fig. 6 Trend of GDP at Jiangsu Taihu Lake basin from 1995 to 2005

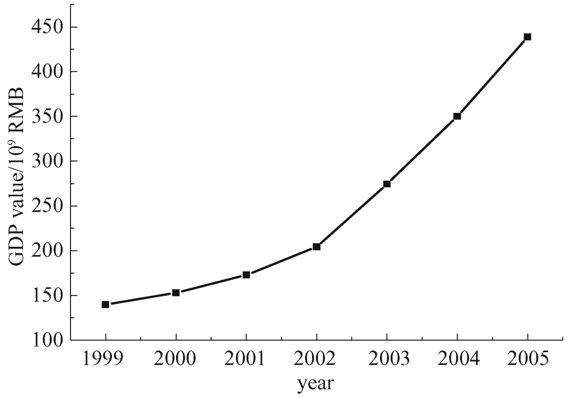


Fig. 7 Trend of total industrial added value in Suzhou, Wuxi and Changzhou from 1999 to 2005

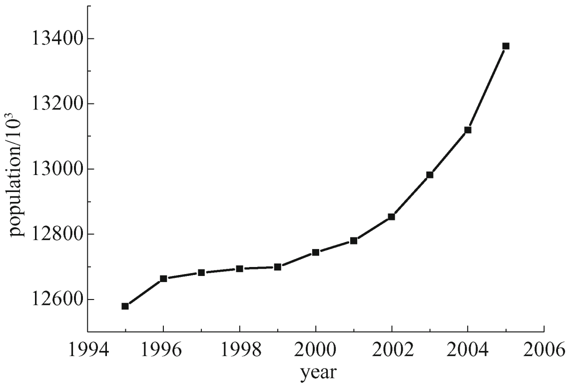


Fig. 8 Trend of population of Taihu Lake Basin of Jiangsu Province from 1995 to 2005

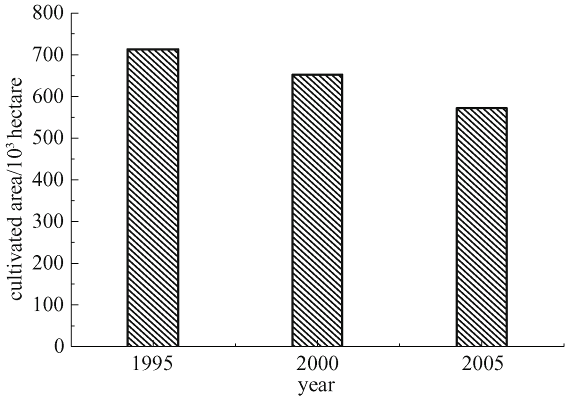


Fig. 9 Trend of cultivated area at Taihu Lake Basin of Jiangsu Province in 1995, 2000, and 2005

As mentioned above, the Taihu basin covers less than 0.4% of the total area of China and possesses only 3% of the total population. However, the GDP of this area constitutes as much as 12% of China's GDP, which is 3.5 times the state mean. Due to a low level of control over environmental pollution, the Taihu basin now suffers from water quality deterioration. This single basin currently accepts 5.15% of the total wastewater, 3.54% of COD, and 2.34% of the ammonia discharge of the entire country. The COD discharge of unit production values is about 233 mg COD per yuan, which accounts for 30% of the average value in China. In addition, COD discharge is about 13 tons per km^2 per area, nine times the state average. Population explosion, rapid economic development, and unreasonable industrial structures have led to a high pollution load per area in Taihu basin, which is the fundamental reason for the eutrophication of Taihu Lake [6].

3.2 Overpollution discharges of point and non-point sources and high amounts of nitrogen and phosphate discharges

The main causes of eutrophication of Taihu Lake have been human-caused pollution discharges at point and non-point sources, and the high nitrogen and phosphate content of such discharges.

3.2.1 Continuous excessive pollution discharge at point sources

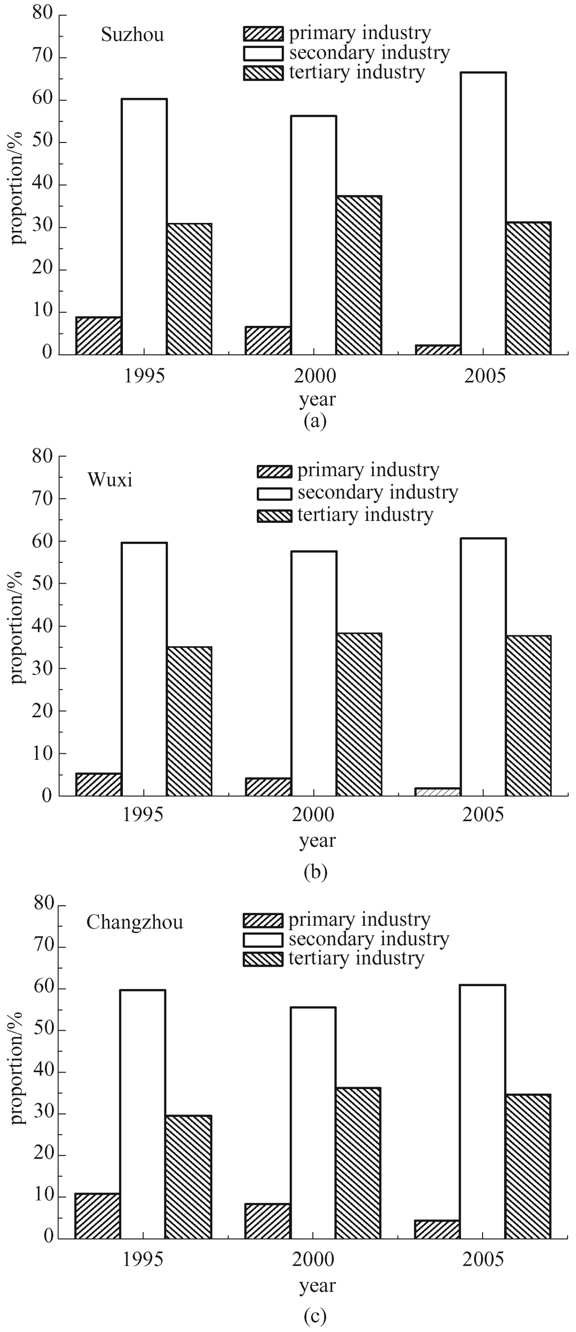


Fig. 10 Changes in the economic structure in Suzhou, Wuxi, and Changzhou city

On the basis of the environmental statistical data of 2006, discharge amounts of wastewater, COD, and ammonia were 2.14 × 10^9 t, 296000 t, and 25000 t, respectively, in the Taihu Lake area, in which 1.484 × 10^9 t of industrial wastewater, 153900 t of COD, and 11500 t of ammonia came from the enterprises located along the lakeside. According to industrial statistics, the heavy pollution industries were those in textile dyeing, chemical engineering, papermaking, steel, and electroplating. The accumulative wastewater, COD and ammonia discharge amounts of the five industries were 8.9 × 10^8 t, 9.5 × 10^4 t, and 6700 t, respectively, which accounted for 57.4%, 66.2%, and 58% of the total industrial discharge of Taihu basin, respectively. The domestic wastewater discharge amount was 0.659 × 10^9 t with 1.333 × 10^5 t of COD and 1.17 × 10^4 t of ammonia.

In light of the charts showing variations in the amounts of annual discharge of domestic and industrial wastewater in Suzhou, Wuxi, and Changzhou (Fig. 11, 12), it is clear that the amounts of discharge of wastewater, COD, and ammonia show a tendency to increase annually. Fortunately, the increase amplitudes were much lower than those of GDP and industrial production values. Furthermore, COD discharge of domestic wastewater decreased significantly after planned sewage treatment plants were put into operation, although the ammonia emissions still kept increasing. This reveals the ineffectiveness of ammonia treatment by the plants and has already led to excessive discharges compared to the environmental capacity as a result of the neglect of N and P treatment. By the end of 2006, there were 172 urban and rural sewage treatment plants in the Taihu basin with a total treatment capacity of 3952800 m^3/d. These sewage treatment plants were supposed to realize a 70% treatment ratio of the amount of wastewater to the covered area. However, a large quantity of domestic wastewater was directly discharged into natural water without any treatment due to poor pipeline infrastructure for domestic sewage. Moreover, most plants had low treatment capability for phosphate and nitrogen removal. All these factors contributed to the high N and P pollution levels in this area.

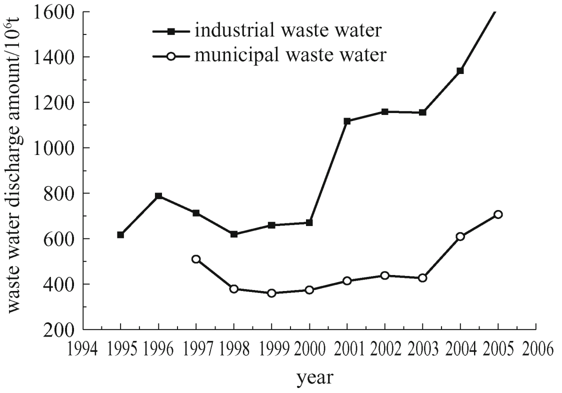


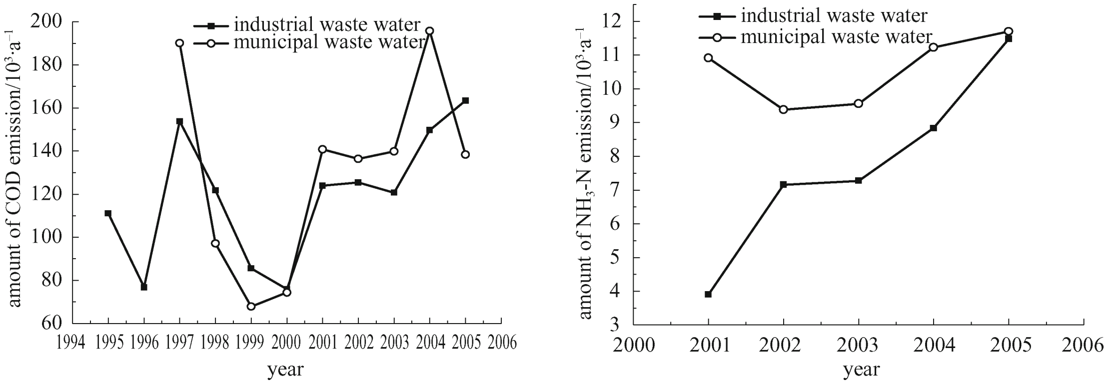
Fig. 11 Amount of industrial waste water and water emission in Suzhou, Wuxi, and Changzhou from 1995 to 2005
(a) Amount of COD emission in municipal waste, industrial waste water, and municipal waste water in Suzhou, Wuxi, and Changzhou from 1995 to 2005
(b) Amount of NH_3-N emission in industrial waste water and municipal waste water in Suzhou, Wuxi, and Changzhou from 2001 to 2005

3.2.2 Discharge of non-point source pollution

Both the discharge intensity and amount from non-point sources in rural areas have been increasing during the past 20 years. Fertilizer may be blamed for such non-point source pollution, while inappropriate irrigation methods, such as flush and flood irrigation, made the situation worse by reducing the amount of fertilizer that is absorbed into the soil where it is applied. According to the 3-year investigative report on Taihu Lake agricultural non-point pollution sources by the Nanjing Soil Research Institute of the Chinese Science Academy, domestic sewage and fertilizer run-off acted as the major contributors of agricultural non-point sources. Among the domestic sewage in the rural area, 24% was directly discharged into the adjacent rivers, 50% infiltrated into the ground water from the surface soil, and 25% flowed in to the ditches. According to the recent census of the Taihu Lake area in Jiangsu Province, discharge from cultivated areas (including dry land and paddy fields) of COD, TN, and TP in 2006 respectively reached 31000 t, 25000 t, and 513 t. The unit of area for fertilizers is still as high as 3.33–4.93 kg/hm^2. Agricultural wastes and stock breeding may also donate large amounts of COD and ammonia. Agricultural non-point sources constitute about 50% of the external pollution sources of Taihu Lake [7], making them another important pollution source.

3.2.3 Pollutants from inflow-rivers

Input of numerous pollutants from rivers is a direct factor in the water quality deterioration of Taihu Lake. On the basis of the Environmental Quality Report of Jiangsu province (2001–2005), China, 21 control sections have been located on the main inflow-rivers and outflow-rivers, comprised of 14 inflow-rivers in the Wuxi and Changzhou regions and 7 outflow-rivers in the Suzhou region. In 2005, the numbers of control sections where the water quality is rated Grade III, Grade IV, Grade V, and worse than Grade V, were 1, 9, 2, and 9, respectively. The



(a) (b)

Fig. 12 Amount of NH_3-N emission in industrial waste water and municipal waste water in Suzhou, Wuxi, and Changzhou from 2001 to 2005 corresponding proportions were, respectively, 4.8%, 42.9%, 9.5%, and 42.9%. Figure 13 shows that the overall water quality in Taihu Lake area was mainly set at Grade IV and worse than Grade V. Ammonia-nitrogen was the main pollutant which affected water quality of the rivers in and out of Taihu Lake.

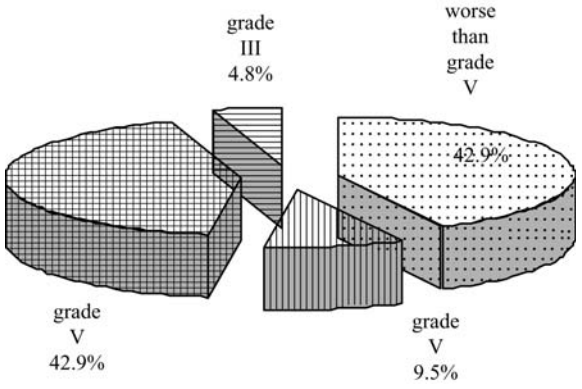


Fig. 13 Statistics of water quality grade of sections of inlflow- and outflow-rivers of Taihu Lake

In 2005, among the 45 joint administrative sections located along the main rivers in the Taihu Lake area, the numbers of those where the water quality belonged to Grade III, Grade IV, Grade V, and worse than Grade V were 7, 11, 13, and 14, respectively. The proportion of the sections where the water quality is ranked Grade V and worse than Grade V added up to approximately 60% of the total (Fig. 14). The major pollution index was ammonia, while petroleum, BOD_5, permanganate index (PI), and VP also served as important pollution indexes.

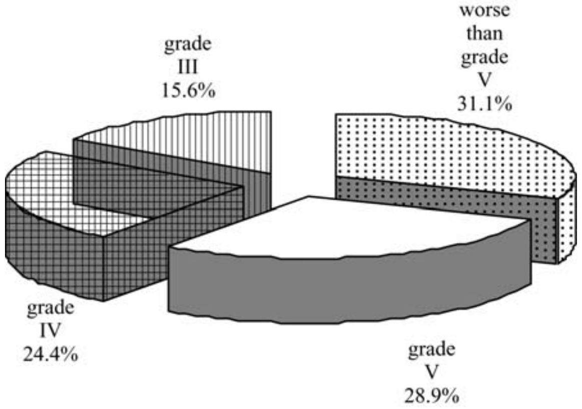


Fig. 14 Statistics of the water quality grade of trans-border sections in rivers surrounding the Lake

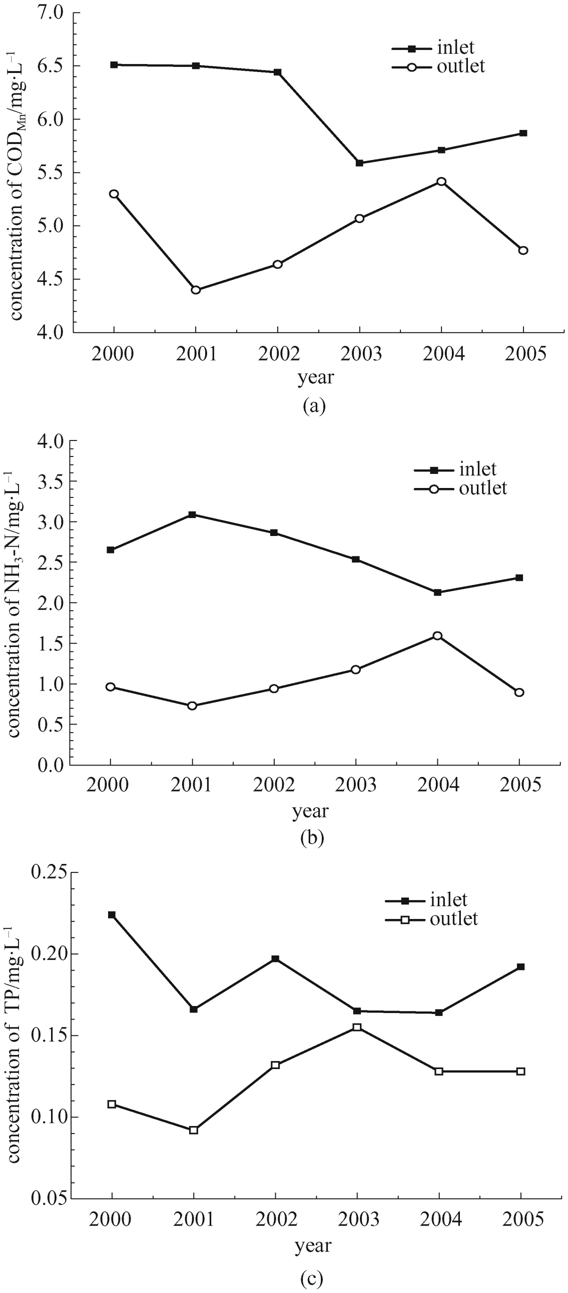


Fig. 15 Trend of concentrations of COD_{Mn}, NH_3-N, and TP in inflow- and outflow-rivers of Taihu Lake from 2000 to 2005

Figure 15 shows that the average levels of PI, ammonia, and TP decreased from 2001 to 2005, while the TP level of selected outflow-rivers increased to some degree. In comparison with the pollution status during the ninth-five year period, the pollution of inflow-rivers in Taihu Lake improved significantly, while the TP level of outflow-rivers clearly increased, except for COD and ammonia.

Figure 16 shows that the level of PI, ammonia, and TP increased at 11 trans-boundary sections of major rivers from 2001 to 2005. In comparison with the pollution status during the ninth five-year period, the pollution due to PI and ammonia at trans-boundary sections did not change significantly while TP clearly increased.

Figure 17 shows that the level of PI, ammonia, and TP of 9 inflow-rivers in Jiangsu Province increased slightly. In comparison with the pollution status during the ninth five-year period, the pollution due to PI and TP of

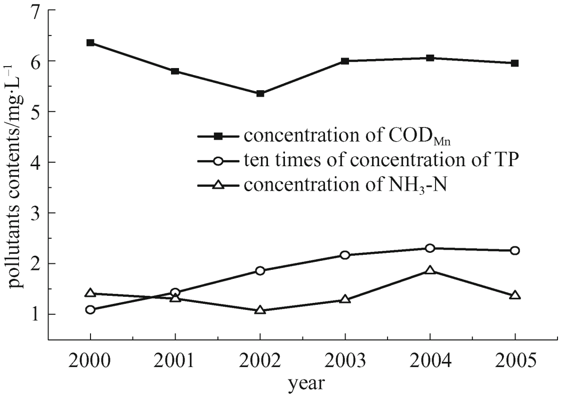


Fig. 16 Trend of main water quality indexes in trans-provincial border sections of Taihu Lake Basin from 2000 to 2005

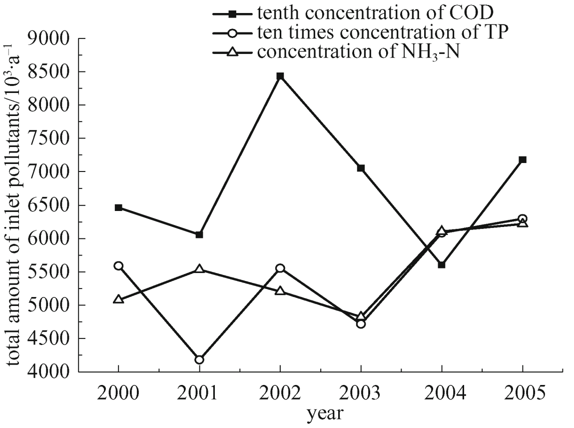


Fig. 17 Trend of total amount of inlet pollutants from the nine key inflow-rivers

inflow-rivers did not change significantly while ammonia clearly increased.

According to the statistical data for the annual inflow water amount, pollution inflow amount exhibited a trend showing a high level period > medium level period > low level period, which implied that the amounts of terraneous pollutants coming from inflow-rivers increased significantly when the inflow water amounts reached their peak values. Especially, fertilizer run-off may become stronger with heavy rain, resulting in the high concentration of TP and ammonia.

3.3 Pollution load release from internal pollution sources

Sediment nutrition release is one of the major internal pollution sources of lakes [8,9]. As a complicated dynamic process, the amount released is affected by multiple factors such as DO, temperature, pH, biological status, and wave-induced perturbation at the lake bottom. It is widely reported that a considerable part of organic phosphorous compounds from various sources can be adsorbed onto the surface of suspended particles in water and settle down to the lake bottom to become sediment by diffusion and sedimentation. Frequent waves and transport boats may initiate a phosphorus outbreak from sediment to the overlying water in a large shallow lake by inducing strong disturbance [10–14]. Consequently, the water quality of a lake is determined not only by internal pollution sources but also by sediment pollution release. The average TN level in the Taihu Lake sediment is 820 g/m^3, with (6.47 ± 4.28) mg/m^{2}d release rate, while that of TP is 90 g/m^3, with (0.551 ± 0.352) mg/m^{2}d release rate. Although the total release amount is not as high as that of internal pollution sources, such release can lead to fast algal growth and eutrophication formation because hydrophytes can quickly absorb the released N and P thus accelerating the release reaction.

4 Strategy of eutrophication control in the Taihu Lake area

In general, the main strategies for the lake's eutrophication control include control and reduction of exogenous pollutants, pollution reduction in inflow-rivers and the lakeside, clean water diversion, reduction of internal pollution sources, and manual algal removal after algal bloom. However, several years of treatment have not achieved ideal results because of inadequate pollution control efforts, inefficient integration of management and technology methods, and poorly-targeted measures. Thus, improving management and targeted technologies should be considered in the following eutrophication control measures for Taihu Lake.

4.1 Control and reduce exogenous pollutants in the Taihu Lake area

4.1.1 Strict control of industrial point-source pollution

There are a great number of industrial enterprises in the Taihu Lake area, with a dominant proportion of medium and small enterprises scattered in distribution, thus the amount of pollutant discharge is very heavy in this area. Consequently, industrial point-source pollution control is one of the main issues in the comprehensive environmental management of this area.

In order to effectively control industrial point-source pollution, several strategies should be implemented. The most effective measures include implementing a more rigorous environmental permit system and discharge standard [15], and giving full play to environmental standard functions.

For example, the newly established *Discharge Standard of Main Water Pollutants for Municipal Wastewater Treatment Plants and Key Industries of the Taihu Area* [16] has created stricter regulations to control industrial discharge. It mainly targets municipal domestic wastewater discharge of the industries in textile dyeing and finishing, chemistry, paper, steel, electroplating, and monosodium glutamate production. In this Standard, more rigorous requirements on COD, ammonia-nitrogen, total nitrogen, and total phosphorus have been established. Also, industries will be forced to suspend production and make rectifications due to over-standard pollutant discharges. By the end of 2008, industrial pollution controls should be strengthened to reach a comprehensive standard of environmental protection, and industries which cannot reach the discharge standard should be shut down. Productive projects should be eliminated if they have the defect of having backward manufacturing technology, heavy pollution or they have difficulty in stably reaching discharge standards. For plants and industries that have been on the list of key monitoring targets in the Taihu Lake area, automatic monitoring and control devices should be required to be installed by the deadline. This will allow real-time monitoring and dynamic management of their production process, and monitoring of the concentration and total amount of pollutant discharge at the same time. Industries are encouraged to undergo advanced treatment on the basis of stably reaching discharge standards, and heavy polluting industries such as the chemical industry should establish and implement clean production before 2012. Moreover, improving the existing license management and implementation system and strictly controlling the total pollutant discharge should be done. Furthermore, the government should strengthen supervision and scrutiny of the implementation of the pollution permit program.

Another countermeasure for the management of industrial point-source pollution is to prevent pollution discharge by vessels and improving emergency treatment. More measures should be taken to increase ships' ability to collect contaminants. For example, among 1.2×10^6 vessels in the Taihu Lake area, all cabins should be installed with oil-water separators and pollution prevention facilities, e.g. inlet trays should be added to boats with oars. Furthermore, measures should be conducted to ensure the normal use of these facilities, improve reception facilities in the coast to match the system in the waters, maintain real-time dynamic monitoring of key vessels, such as dangerous goods carriers, passenger ferries and tourist ships, and accomplish the construction of an emergent rescue system for vessel pollution accidents as soon as possible.

4.1.2 Management of municipal wastewater and garbage

To enhance the overall control level over existing municipal sewage treatment plants, the following measures should be taken: increasing the coverage of a counterpart pipeline system and perfecting the pipeline systems that are already completed or under construction; improving the diversion system of rain and sewage water and clearing away the sewage outfall discharging directly into the Taihu Lake; joint construction of sewage treatment plants are recommended, and sewage from the peri-region can be piped into the joint sewage treatment plants for disposal; establishing a supervisory and scrutiny system for sewage treatment plants, and building an on-line monitoring system for sewage influents and effluents; building a more reasonable evaluation index system that can control environmental efficacy and operation efficacy, and constructing a supervisory and evaluatory institution.

Ecological conservation technologies which primarily utilize sewage as a resource to remove total nitrogen and phosphorus are recommended in rural domestic sewage treatment [17]. It is further recommended that steps should be taken to optimize the combination of biological and ecological treatment technologies, realize centralized and decentralized treatment of rural domestic wastewater in the Taihu Lake area, make comprehensive utilization of resources, and forbid the sale of phosphate detergents.

Some other measures are also helpful: improving the efficiency of garbage disposal and making resourceful treatment of the garbage; enhancing supervision of waste landfill sites; promoting a better management level of landfill operations; improving seepage control constructions of landfills.

4.1.3 Non-point source pollution prevention and control

Firstly, agricultural area pollutants should be controlled. The usage of chemical fertilizers could be reduced by adjusting the plant structure and arrangement of agricultural breeds, and by popularizing formula fertilizer. Regulating the production behavior of peasants could also be helpful for agricultural area pollution prevention, which can be realized by establishing and adopting a limited agriculture technology standard in protected areas of water resource in order to restrict fertilization quantity, frequency, and type. Phosphorus loading from agricultural non-point source pollution is one of the main reasons for eutrophication in Taihu Lake. Investigations have showed that improving the administration of ground surface and the types of fertilization can efficiently reduce the loss of phosphorus. For example, ground cover, straw covering, and row or hole application of fertilizer can reduce phosphorus loss by 80%–90% [18]. Furthermore, construction of an ecological ditch system with interception function by planting nitrogen- and phosphorus-hypertolerant plants could alleviate water pollution by nitrogen and phosphorus loss from farmlands. It would be satisfying if the remaining nitrogen could be controlled within 80 $kg/(hm^2 \cdot a)$ [19] over guaranteeing a high-yield of farm crops by using foreign experience for reference.

Secondly, pollution from livestock and poultry raising should be prevented. Dry clearing of excrements is recommended to be adopted in the livestock and poultry industries. A fermentation pool of solid waste disposal could be built to produce biogas and organic fertilizer so as to realize recycling utilization of resources. Reduction of the use of inorganic fertilizer could be realized by strengthening the effective utilization of organic fertilizers such as human and animal manure.

As to aquaculture, pure seine culture in the Taihu Lake area should be gradually abolished while culture in recycled water should be popularized. Pond culture-wetland systems could be constructed by the rational distribution of aquaculture ponds to utilize recycling of culture water and reduce environmental pollution. Developing an ecological culture by stopping the usage of baits is another good measure for protecting the water.

4.2 Pollution control for inflow-rivers

Inflow-rivers should be utilized in carrying out water purification, basin pollution interception and ensuring regional ecological safety. One method is to perform wetland protection, restoration, and reconstruction because wetlands have sound nutrient removal and ecological protection functions [20–21]. Hydrophytes should be established in the Taihu lakeside area to restore the lake and river wetland functions of the Taihu basin. A nature protection zone and wetland protection zone should be established in the basin, and the present waterbodies and beaches should be used to reconstruct a wetland protection zone. In addition, paddy fields can be used to establish wetlands. The other method is to construct ecological forests and establish ecological purification projects for inflow-rivers [22]. An ecological insulation band can be established by constructing a watercourse defense forest, lakeside defense forest, and water resource protection forest. Various ecological purification projects should be carried out such as creating a watercourse ecological bank and bank ecological buffer band, *in situ* and transposal treatment of river water, riverway ecological remediation, and influx-intensified water purification [23].

4.3 Lakeside ecological remediation

A buffer zone-lakeside composite ecosystem can be constructed by lakeside ecological remediation and buffer zone establishment. The strong pollutant assimilation ability of a grass-type ecosystem is used to purify water [24]. Further, such a composite system can alleviate man-made interference, cut down inflow pollutants, strengthen the self-purification capacity, and create sight diversity and a fine cycle of a self-maintaining lakeside ecosystem. A set of natural lakeside ecological remediation techniques should be developed, including ensuring bank fundus improvement, habitat improvement, vegetation community optimization and construction, ecological sight restoration, and large-scale lakeside ecological construction at heavily polluted lake areas. In addition, other compensatory actions should be taken into consideration such as wastewater treatment and water environment management techniques for the lakeside area, and water quality improvement and ecological remediation techniques for the small-scale lake of the buffer zone [25].

4.4 Clean water diversion

Work on water resources regulation through the project ‘Diversion water from Yangtze River to Taihu Lake’ should also be allowed to proceed well to promote a new turn of projection constructions for the treatment of the basin. Dredging should be done to magnify the volume of the Xinmeng River, widen the Wangyu River, control the contamination of waters in the western part of the Wangyu River, and then the discharge project could be implemented.

Improving the outlet transport water capability of the lake should be another important part. It could be realized by three major projects. Firstly, partial dredging of the water body in the Taipu River would speed up the construction of reinforcements for the sluice gates of Taipu River. Secondly, implementation of the Taijia River project could ensure the quality of downstream water supply. Thirdly, drainage projects in the Pinghu pool, the Changshan River, and Jinghui Bay could improve the ability of discharging south towards Hangzhou Bay, accelerating the water flow in the plains area of the eastern part of Hangjia Lake, improve regional water quality, and decrease the pressure of regional flood prevention.

4.5 Dredging

Pollutants discharged from urban and rural areas accumulate in the sediment of river and lakes, and the pollution released from sediment to overlying water is rather common due to the disturbance induced by waves and boats. Such examples have already become an important secondary pollution source after sewage and agricultural non-point sources. Sediment dredging is a key measure in the eutrophication treatment of Taihu Lake [26]. According to the sediment depth and nutrition distribution characteristics of Taihu Lake, additional investments should be made for Wulihu and Meiliangwang ecological dredging. The range of sediment dredging should be extended, and the dredging accuracy should be controlled to minimize the returned sullage. Dredged sediment should be disposed in time. A new environment-friendly dredging device with low diffusion and high solid ratio should be developed to make real toxicant-polluted-sediment removal in shallow lakes. Considering both sediment pollution characteristics and project traits, the ecological model solidification bank technique and polluted sediment heat treatment technique should be studied. The objective of sediment heat treatment is to detoxicate the sullage and make it a new resource, with high addition values that can be used as china clay for gardening, fillings utilized in sewage treatment for non-point sources, micro-pore materials for adsorption, and construction materials.

4.6 Manual algal removal

Large-scale dredging of the blue algae, especially in the areas which are important water-source bases before and after the outbreak of cyanobacteria blooms should be done, as well as preventing water pollution caused by dead blue algae. Other measures include: building a specialized mechanism for algal dredging, wholly developing the strength of the masses and efficiently organizing the public, localization and making contracts for algal dredging; motivating the enterprises and institutions in the Taihu Lake area to fish the blue algae by using their staff, with assurances of guaranteed expenditure-funds and proof of effectiveness; building a professional dredging company equipped with professional and effective dredging ships to dredge in key waters; delivering of the blue algae to designated places by professional work teams; building a central area for blue algae storage and stacking; making the blue algae innocuous through recovery methods such as making them into organic fertilizer and exploring the methods of power generation from rotted substance, and avoiding secondary pollution.

5 Conclusions

Eutrophication control of Taihu Lake involves systems engineering. The philosophy of seeking both temporary and permanent solutions and combinations of technology and management should run throughout the control process. It is critical to take full advantage of technical personnel and attach great importance to technological and scientific methods.

In addition to the execution of the strategies mentioned above, problems exposed during water pollution prevention should also be improved. Firstly, a regular inclusive survey of pollution sources in the Taihu basin should be carried out to solve the problem of inaccurate and inadequate pollution data. Secondly, key problems, such as dephosphorization and denitrification, advanced treatment of industrial wastewater, treatment of a non-point source, ecological remediation, and advanced treatment of drinking water should be tackled. Thirdly, inter-departmental cooperation should be strengthened to improve management ability. Lastly, continuous improvement of the statutes concerning the environment and formulating strict law-enforcement procedures and increasing the intensity of law enforcement must be done so as to ensure the effective implementation of environmental laws and regulations.

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