Journal of Lake Sciences, Vol. 10, Suppl., pp101-110, 1998.

Pollution Sources and Ecological Control Approaches to Eutrophication of Taihu Lake*

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Abstract: *In accordance with the natural, geographic, and ecological characteristics of the Taihu Lake Basin, and the relation between the water body of Taihu Lake and its surrounding environment, an area, which has tight relevance with the water environment of Taihu Lake, was token as the main investigation region. The area was named as the Taihu Lake Region. Some factors, such as TN, TP, COD_{Cr} that characterized the main environmental problem, the eutrophication were selected when conducted the pollution sources investigation on in Taihu Lake Region. The categories, distribution, pollution contribution to the Lake of different pollution sources, as well as the routes of pollutants entering the Lake were basically made clear. Pollution sources that must be preferentially controlled and the direction of controlling those main pollutants, such as TN, TP, COD_{Cr}, were proposed. Base on the investigation, a series of eco-systematic approaches for controlling Taihu Lake eutrophication were put forward. They are eco-system regulation, nutrient substances transferring along food chain, trophic masses degrading step by step along the route from a pollution source to the Lake, building ecological preventive zone of the Lake, as well as the ecological measures for point sources treatment and so on.*

Keywords: *Pollution Sources, Ecological Control, Eutrophication, Taihu Lake*

1. Introduction

Being not only the third largest fresh water lake of the country, but also one of the most important water resources to the Changjiang River Delta region, including Suzhou, Wuxi, Changzhou and Pudong Economic Development Zone of Shanghai, the Taihu Lake plays a variety of roles in such fields as drinking water supply, industrial and agricultural production use, flood control, transportation, aquiculture, tourism, etc.. Recently, due to rapid growth of the economy, expansion of the population and steady intensification of the human activities, pollution and eutrophication of Taihu Lake has been increasingly aggravated. This leads to deterioration of the water quality in parts of the waters and the occurrence of several algal blooms, which has brought about certain losses to the industrial and agricultural production and adverse impact on the people's

* Received 1997-02-25; accepted 1998-03-27.

living and public stability.

In order to explore the reasons of the eutrophication of Taihu Lake, to seek for proper approaches to control the eutrophication and to determine focal points for control of the eutrophication, we have accomplished initial analyses of the major indexes of eutrophication (TP, TN and COD_{Cr}). The routes and amount of the pollutants being generated and entering the local water body and then Taihu Lake were analyzed. On such a basis, we bring forward a systematic control program for Taihu Lake eutrophication in ecological approaches.

2. Research Scope

The Taihu Lake Basin borders on the Changjiang River on the north and faces the sea on the east and the southeast. On the west and the southwest, with the Maoshan Mountains, the Jieling Mountain and the Tianmushan Mountain as watersheds, it is separated from the Qinhuihe, Shuiyangjiang and Qiantangjiang River Valleys. The basin is 36 500 km^2 in total area with Taihu Lake in the center. And the lake has a water surface area of 2 338 km^2 and a total water storage capacity of about 4.76 billion m^3 at the normal water level.

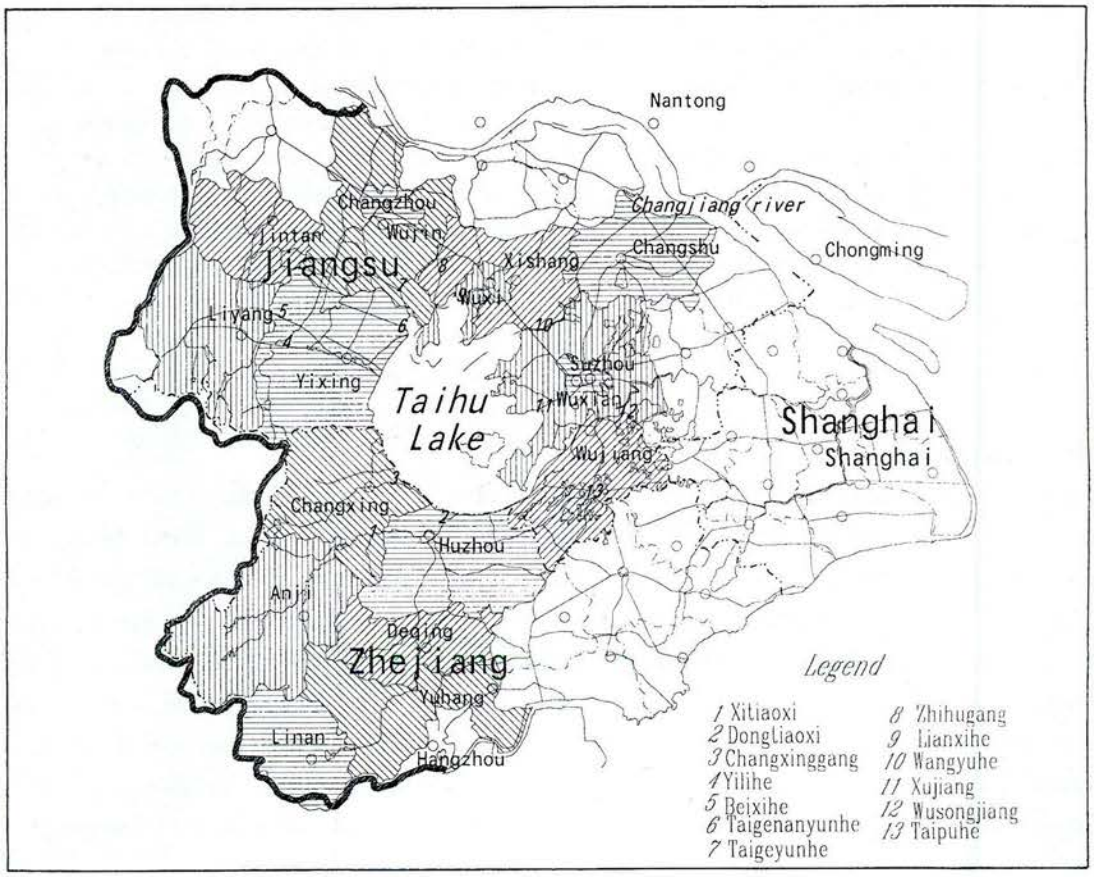

Fig. 1 Research scope

The Taihu Lake Basin can be divided into two, the up-stream area and the down stream area, with the Taihu Lake as its demarcation line, which goes linearly from Zhihugang of Xishan City, Jiangsu Province to Wulugang of Huzhou City, Zhejiang Province. The rivers and water courses connecting with the lake reach 224 in number, pertaining mainly to the Tiaoxi, Nanxi, Taihu Lake, Grand Canal, and Huangpujiang water systems. The in-flowing waters come mainly from the Tiaoxi water system including the East and West Shaoxi Rivers, Changxinggang River, etc., and from the Nanxi water system including the Nanxi River, Taige Canal and other rivers in Liyang and Yixing areas. The Grand Canal also has a small volume of water interflow with the Taihu Lake. In the down stream area, the Wangyuhe River and Taipuhe River are the major water courses leading the Taihu Lake water into the Changjiang River and the sea.

The research scope is determined mainly to cover those areas directly affecting by or closely related to the changes in water quality of Taihu Lake, and the areas alongside the Wangyuhe River that might be used as the water course to divert water from the Changjiang River to Taihu Lake. So, areas involved in this research are mainly those run through by the Liangxihe River, Zhihugang River, Taige Canal, South Taige Canal (Yingcungang River), Beixihe River, Yilihe River (Nanxi), Changxinggang River, Xitiaoxi River, Taipuhe River, Quajingang River (Wusongjiang River), Xujiang River, Wangyuhe River and those surrounding the lake. Suzhou, Wuxi, Changzhou, Huzhou, Changxing, Deqing, Anji, Wujiang, Wuxian, Xishan, Wujin, Yixing, Liyang, Jintan and Danyang are the cities and counties involved (Fig. 1)

3. Sources of the Materials

In addition to the materials collected by Nanjing Institute of Environmental Sciences, NEPA, during special investigations, the following basic materials were used for analysis:

The 1994 statistics of the counties and cities related to the Taihu Lake Region;

The materials and data from the national key scientific and technological project-- "Protection of The Water Quality of The Taihu Lake Water System", from research projects and investigations of NIRES of NEPA, Nanjing Institute of Geography and Limnology of the Chinese Academy of Sciences, and other research institutions, from Jiangsu Province Environment Protection Bureau, Jiangsu Province Environment Monitoring Centre, Zhejiang Province Environment Monitoring Centre, and Environment Protection Bureau and other associated institutions of Wuxi, Suzhou, Changzhou and related counties and cities in the Taihu Lake Region.

4. Results

4.1 Of various entering routes, rivers being the most important route from which nutrient salts and organic pollutants enter the Taihu Lake.

The nutrient salts and organic pollutants enter Taihu Lake mainly by ways of in-flowing

rivers, atmospheric precipitation, passing vessels, aquatic culture, tourism, surface run-offs, etc., of which the rivers rank first in volume of transfer. Fig. 2 shows the distribution of the in-flowing transfer.

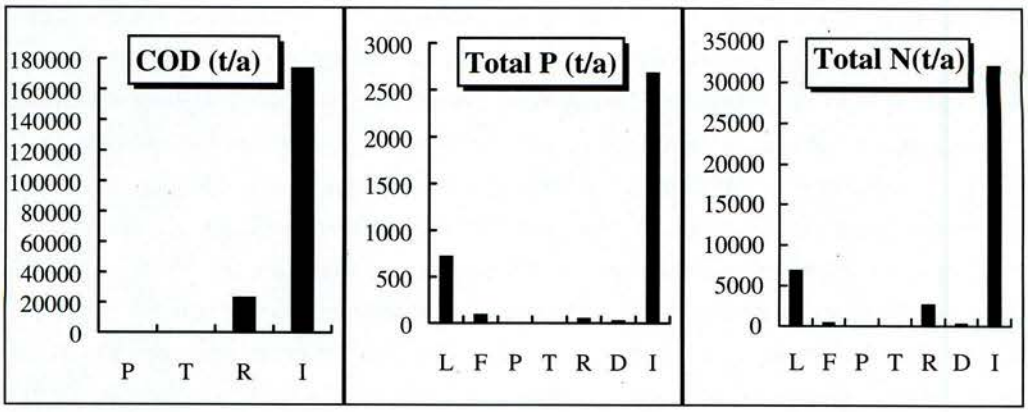

Fig. 2 Major sources of pollutants in the Taihu Lake and their distribution

P=Passing vessels
T=Tourism
R=Rainfall
I=In-flowing rivers
L=Lake mud
F=Fish rearing in net cages
D=Dust precipitation

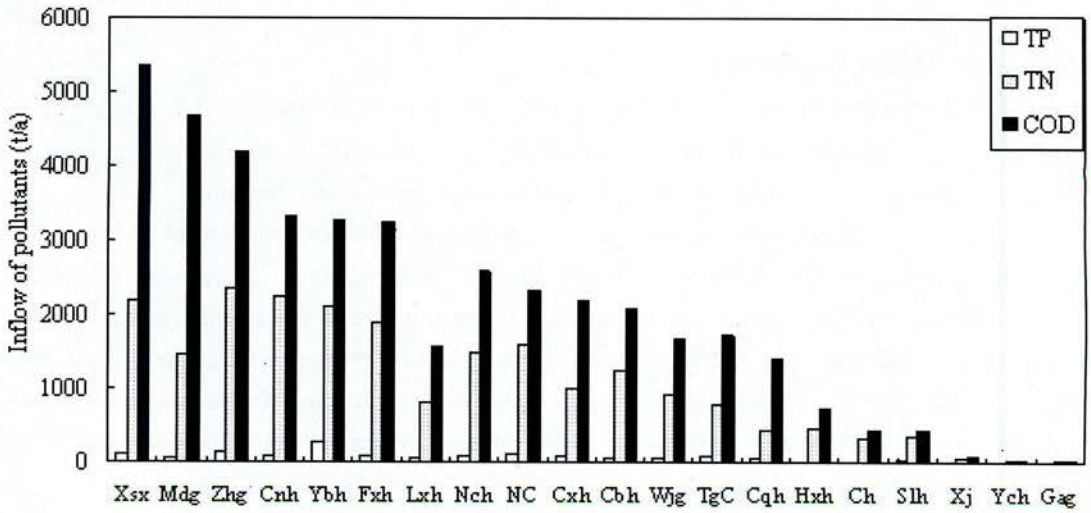

Fig. 3 Loads of the major pollutants in the 20 chief in-flowing rivers

Xsx=Xitiaoxi, Mdg= Maoerdonggang, Zhg= Zhihugang, Cnh= Chengnanhe, Ybh= Yibeihe, Fxh=Fuxihe, Lxh= Liangxihe, Nch= Nancanghe, Nc= New Canal, Cxg= Changxinggang, Cbh= Chengbeihe, Wjg= Wujingang, Tgc= Taige Canal, Cqh= Caoqiaohe, Hxg= Hexixingang, Ch= Chenghe, Slh= Sanliqiaohe, Xj= Xujiang, Ych= Yuechenghe, Glg= Gulougang

4.2 Most pollutants was brought into the lake by Xitiaoxi, Maoerdonggang and Zhihugang Rivers

There are about 224 rivers flowing in or out of Taihu Lake, of which the rivers in the up-stream area on the west and the southwest sides of the lake have higher water flow, thus carrying larger volume of pollutants into the lake. Fig. 3 shows COD_{Cr}, TP and TN loads of the 20 chief rivers.

4.3 Major sources of the pollutants

Of the pollution sources of various types, total P comes mainly from domestic pollution sources, *total N* from domestic pollution sources and farmland run-off and organic pollutants from domestic and industrial pollution sources. The analytical results are shown in Fig. 4.

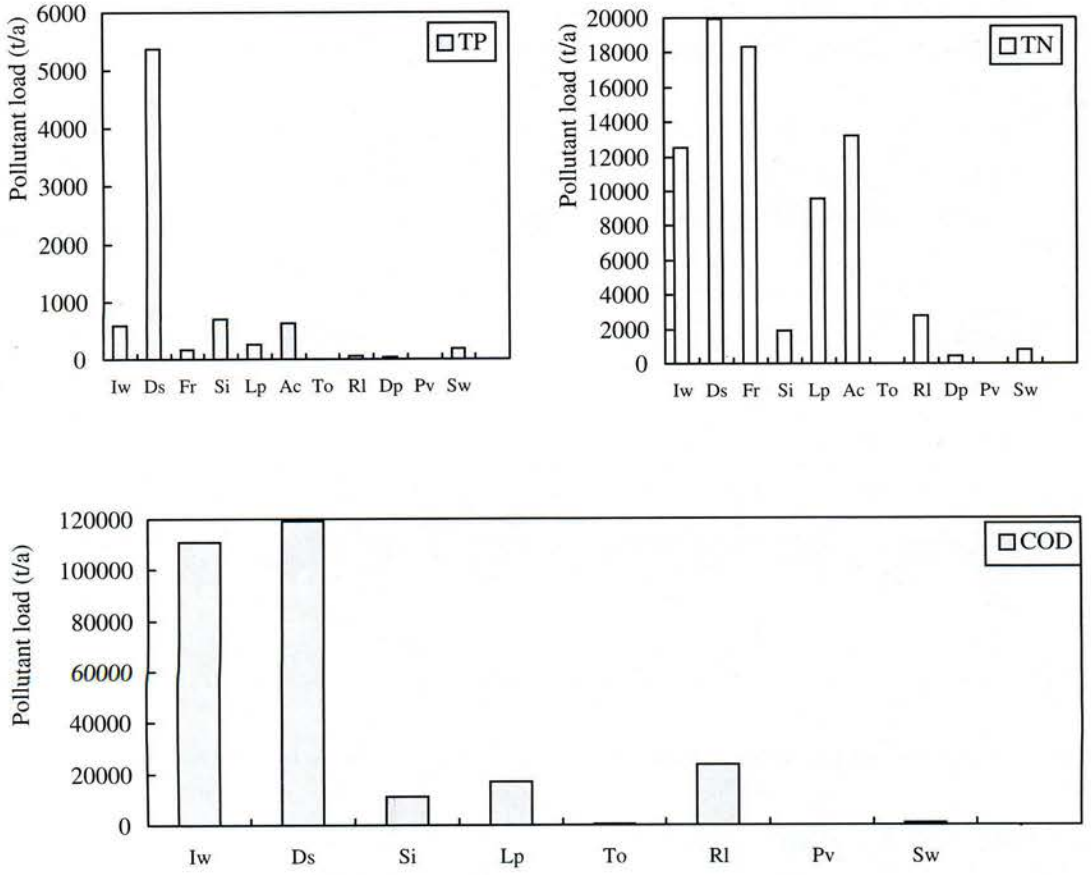

Fig. 4 Pollutant load contribution of the major pollution sources in the Taihu Lake region

Iw= Industrial waste water, Ds= Domestic sewage, Fr= Farmland run-off, Si= Scattered inhabitants, Lp= Livestock and poultry raising, Ac= Aquiculture, To=Tourism, Rl= Rainfall on the lake, Dp= Dust precipitation, Pv= Passing vessels, Sw= Soil and water losses

4.4 From the five-km-wide belt surrounding the lake, the pollutants entering the water body account for a large proportion

A five-km-wide belt surrounding the lake is designated as a Taihu Lake water resource protection zone, whose load of pollutants affects directly the water quality of the Taihu Lake. The organic pollutants (COD_{Cr}), total N and total P discharged into the water body from this area accounts for 12%, 26% and 14%, respectively, of the total pollutant load in the water body of the Taihu Lake Region (Fig. 5).

4.5 Key points of pollution control

From the above analysis it is known that the key points and direction of controlling external pollutant load from entering the lake should be defined as follows.

a) The transfer of pollutants in the rivers leading into the lake should be controlled.

b) The Xitiaoxi River, Zhihugang River, Yibeihe River and other major rivers are key points for control.

c) The key point controlling total P is to control domestic pollutant sources; the key point controlling total N is to control domestic pollutant sources and farmland run-off; and controlling COD_{Cr} domestic pollutant sources and industrial pollutant sources.

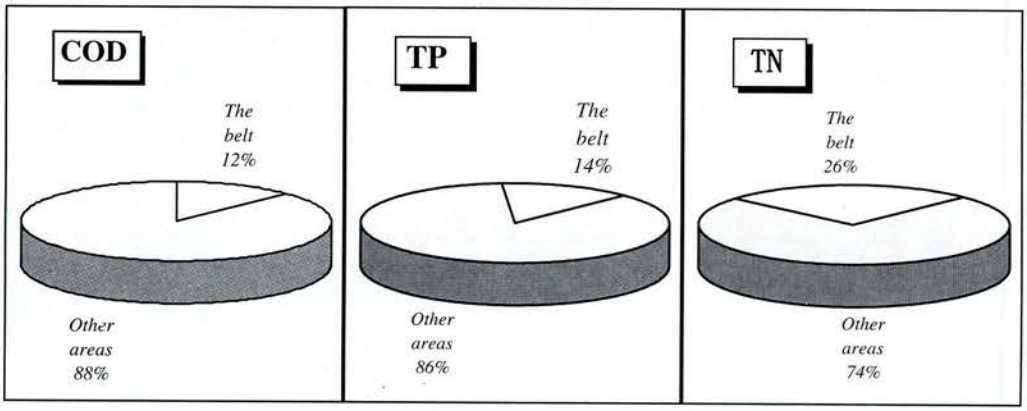

Fig. 5 Proportions of the pollutants coming from the five-km-wide belt surrounding the lake

5. Ecological Control System

The issue of eutrophication of the lake is a kind of ecological disturbance problem. The solution of any ecological problems must be approached to by way of ecological control and regulation. Considering the ecological characteristics of the Taihu Lake region, the feasibility of the ecological regulation, and the fact that the country's economic bearing capacity is not strong enough, and that any single measure can not solve the problem, we brought forth an ecological control system for the Taihu Lake eutrophication.

The ecological control system for Taihu Lake eutrophication consists of eight sub-systems,

independent from each other and related to each other as well, thus forming an integrated system.

5.1 Lake ecological control system

a) A rational ecological structure is to be built up to enable the excess nutrient salts (N and P) to transfer from the water body to economic fish by way of food chain, and finally to be removed out of the lake by catch of the fish.

b) A large-economic-water-plant-based ecological control zone, 300-500 m wide, is to be built up on the shallow water flats alongside the shore of the lake. The plants can not only be used as industrial raw material, but also intercept nutrient substances carried into the lake by run-offs along the shore, suppress propagation of algae and absorb excess nutrient salts in the water body. And the excess nutrients can thus be removed from the lake by harvesting the plants.

5.2 Shore ecological control system

On both sides of the dike surrounding the lake ecological protective forest belts are to be built up. On the water side, water-tolerant trees are planted and on the slope of the dike turf grasses are grown; on the other side 100-300 m wide protective forest belts are to be erected.

Their functions are:

a) To prevent damage of the dike and soil erosion by rains and waves;

b) To uptake and degrade nutrient salts in the soil on the shore and in the upper groundwater;

c) To check the influence of run-offs and groundwater from farmland surface on the lake.

5.3 In-flowing river ecological control system

The control zone of the system covers the areas alongside the in-flowing rivers and around the river mouths. On both sides of the rivers, ecological protective forest belts are to be built up. On the water side of the dikes, large water plants, like reeds, and on the slopes turf grasses and water-tolerant trees are grown, and on the inner side of the dike, 30-50 m wide protective forest belts are to be built along the rivers for miles.

Their functions are:

a) To uptake nutrient substances and mud in the water body by the plants on the riverside.

b) To reduce velocity of the flows and thus to control erosion of the riverbeds by water, which facilitates sedimentation of P- and other nutrient-adsorbent silt particles.

c) For the protective forest belts on the inner side to absorb nutrient substances from the non-point source of farmlands, thus to reduce the volume of pollutants going into the rivers along with surface run-offs and leaching of upper groundwater.

5.4 Township and village industry (TVI) and small town point sources control system

In combination with the comprehensive renovation, and environmental protection program for rural small towns, trade readjustment and deployment rationalization of TVIs was to be carried

out. TVI plants and the plants demanding pollution treatment in particular are to be moved to assigned industrial zones, so their pollution can be treated in an integrated way. Nutrient substances like N, P and some others can be eliminated from the wastewater through ecological engineering of waste water treatment, with artificial wetland as an example.

5.5 In-depth treatment of urban waste water by ecological engineering

Wastewater treatment plants are to be built to treat all the urban sewage. To eliminate the waste water of nutrient salts like P and N, augmentation of an ecological engineering treatment link like artificial wetland may be taken into consideration.

5.6 Agricultural non-point source control system

a) To change the cultivation system. Within the distance of 500 m on both sides of the in-flowing rivers, vegetable gardens ought to be replaced by farmland with grain crops.

b) To popularize scientific fertilization. The application rate of chemical fertilizers should be controlled and the use of organic manure is encouraged.

c) To treat the sewage from animal and poultry farms through biogas digesters. The biogas sludge can be used to feed fish. Thus, agricultural ecological engineering can be realized.

5.7 Ecological regulatory role of water conservancy projects

By making use of the water conservancy projects built at the major in-flowing rivers to prevent seriously polluted water from flowing into the lake and to regulate the water storage of the lake to a proper level.

5.8 Establishment of a computerized expert system for supporting decision-making for the Taihu Lake ecosystem regulation

A computer mathematical simulating system covering lakes, rivers, rainfalls, run-offs, organisms, discharge of pollutants and their transfer, transformation, fate and interactions in the system and the role of artificial regulation, should be developed for predicting the changes in the ecosystem. It may play a supportive role in decision-making for pollution control, eutrophication control and the system regulation.

6. Important problems requiring further study

In order to control water pollution and eutrophication of the Taihu Lake effectively, it is essential to conduct comprehensive and systematic investigations of the basic information of the Taihu Lake ecosystem and its various affecting factors. On such a basis, the priority in research should be given to the following issues:

1) Technology for artificial regulation of the Taihu Lake ecosystem and computerized expert system supporting decision-making;

2) Rational structure and mechanism of a benign cycle of the Taihu Lake aquatic ecosystem;

3) Processes of transfer of nutrient salts and their transformation in the Taihu Lake, laws of distribution and control means;

4) Genesis of the algal blooms in the Taihu Lake and their control means;

5) Role of large water plants in nutrient transfer and rational distribution, scope of adaptability and artificial regulation schemes for large water plant ecological control zones in the lake;

6) Means of agricultural ecological engineering control of non-point source pollution;

7) Monitoring system of the Taihu Lake ecosystem;

8) Technology for artificial wetland projects to eliminate N, P and organic pollutants from domestic sewage.

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