Journal of Environmental Sciences (China) Vol. 4, No. 2, pp. 114−128, 1992 ISSN 1001-0742

Regional ecosystem analysis of Chaohu Lake and its surroundings

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Abstract — Chaohu Lake and its surroundings constitute a complicated system where many ecological problems have accumulated for years. In addition to physical, geological and biological factors, chemical factors are also important for the dominance of *Microcystis* and its bloom. Nutrient elements are abundant in the lake water with total phosphorus concentration of 0.142 mg/L and the total nitrogen of 1.68 mg/L. Evidence suggest that it is light which limits the algal development in the growing seasons. To reduce allochthonous phosphorus load, first from the point sources, and to change the aquatic conditions back to P-limiting state by various means is the prior approach while an integrated treatment of the whole environment is needed to stabilize the system.

Keywords: lake water quality; eutrophication; catchment; ecological factors.

DETERIORATED ENVIRONMENT

Eutrophication of the water is the greatest impairment of the functions. Algal bloom (mostly *Microcystis*) can be observed in the lake. Another problem is that the lake water is highly turbid, containing a large quality of suspended solids. This decreases the light intensity in the water and inhibits the photosynthesis rate of algae in the middle and lower layers, thus making blooming algae more dominant in the aquatic environment.

Organic matter from algae decomposition and from untreated municipal and industrial waste water is of high concentration. Part of the pollutants enters the water plant and effects the quality of drinking water.

The fourth problem is the lack of macrophyte along the lake shore. The submersed and emersed macrophytes disappeared in most parts of the littoral belt in early 1960s, causing 5th ecological problem—bank erosion.

According to a previous investigation (Anhui Institute for Environmental Protection, 1986), there was 44 km of lake shore with serious erosion and 20 km with slight erosion, resulting in 1340000 m^3 soil (500000 tons), entering Chaohu Lake and causing land loss of 240 mu (16 hectares) per year. The land loss aggravates the population stress in the area.

The decline of quality and quantity economic aquaculture products. The production of highvalued fish decreased 78% by 1980 in comparison with that in 1952. *Coilia ectenes*, a fish with very low economic value, has become the dominant species in Chaohu Lake.

The biota has changed greatly in Chaohu Lake since 1960. Besides the disappearance of emersed and submersed plants, herbivorous fish and detritus feeders declined, secondary carnivores were also reduced and primary carnivores (zooplankton feeding fish) became the dominant fish species. *Microcystis* forms the majority of the biomass. This biota constitutes a simple and weak food chain with most primary productivity unable to convert into secondary productivity in an efficient way. The ecosystem of Chaohu Lake (Fig. 1) is simple with few species, and a lack of species interactions.

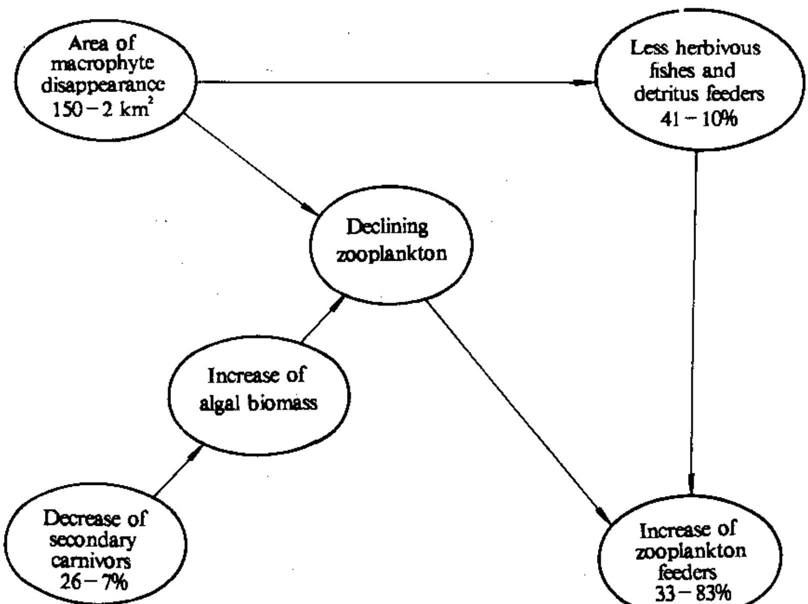

Fig. 1 Changes of ecological composition in Chaohu Lake from 1950s to the present

MECHANISMS OF EUTROPHICATION IN CHAOHU LAKE

In aquatic ecosystems, ecological factors have complicated interactions. Factors which most strongly affect the degree of eutrophication of lake systems are the lake's location, climate, hydrology, light intensity, bio-community structure, geochemistry, the morphology of lake basin as well as many anthropogenic factors. Several factors have been recognized important regarding dominance by blue-greens (Shapiro, 1989).

Physical and geological reasons

Chaohu Lake is the transitional zone of sub-tropical and temperate climate. The annual average air temperature is 15 – 16 ℃ and the July temperature is 28 – 30 ℃. Its location is close to the sea and it is surrounded by a fluvial plain. This causes the area to be greatly influenced by the monsoon from the Pacific Ocean and the East China Sea. The average wind speed is 4.1 m/s. There are frequent windy days in a year and it often causes big wave in the lake.

Chaohu Lake is a shallow lake. The wind-caused physical movement of the lake water stirs the water violently and no stable stratification is observed in all seasons. The sediments are easily stirred up and the physical interaction of sediments and water is strong. The water is always muddy and the water transparency is low, with average Secchi Disk depth about 20 cm. Because of the shade produced by the massive suspended sediments, little light exists in the lake water except in the top surface layer.

The elevated temperature, low amount of light in the water column and a high rate of nutriment release caused by the strong sediment-water interaction are some of the physical reasons for the dominance of *Microcystis* (Shapiro, 1989; Sas, 1989).

Geological factors usually have an important effect on the feature of lacustrine ecosystems. The lakes accept water together with its dissolved and suspended materials from their catchments. The geochemical properties of the catchment soil and bedrock greatly influence the nutrient level and the other properties of the water and sediments of the lakes (Lermen, 1980).

The soil in the mountain area originates from the bedrock of weathered debris of volcanic rocks. This soil contains mainly coarse and medium sand, with a very small amount of clay. Its loose structure results weak in resistance against erosion. Paddy soil mostly originates from loess earth and contains mainly fine clay. It is quite resistant to surface erosion. But some of it contains Fe-Mn nuclear and has a column structure in its lower part. When such a soil profile is exposed in an alternating dry-wet atmosphere, its physical properties then become rather weak and the soil often collapses. This situation happens in many areas along the bank of Chaohu Lake and causes steep bank slopes.

The morphology of the lake basin is shown in Fig. 2. The sediment is composed by Amphibol, Epitode, Zircon, Tremolite, Gaenert and other silicate minerals. The sediments contain organic matter (1.13%), total nitrogen (0.067%) and total phosphorus (0.051%). The modern sediment has a thickness of one meter on average and the thickest part is 2 – 3 meters thick. The sediments are composed of fine sand and clay (Tu, 1990). The high turbidity of the lake water is mainly caused by light diffusion of many fine mineral particles.

Biological reasons

The most important feature of water eutrophication is an abnormal biomass of phytoplankton and macrophyte in the water ecosystems. The interactions of different species of organism form a complicated picture in the aquatic system. They include the competition for energy and nutrient, grazing and chemical interactions.

Chaohu Lake is not like other shallow eutrophic lakes which have good macrophyte vegetation. Chaohu Lake has a simple ecological structure with dominance of the bluegreen algae *Microcystis*. In winter diatoms sometimes dominate. The phytoplankton species which most frequently appear in sample collection are *Microcystis aeruginosa, Microcystis flos-aquae, Chroomonas acuta, Anabaena spirioides, Aphanizomenon flos-aquae, Cryptomonas erosa, Cryptomonas ovata, Cyclotella stelleigera, Eudorina elegans, Surirella capronii* (Tu, 1990). The lake does not have complicated biotopes. The littoral zone near the shore is small, with reeds as the dominant plant and has very small ecological function in the aquatic ecosystem.

The major fish species in the lake are *Coilia ectenes, Hemisalanx Prognathus Regan, Erythrogulter oxycephaloides, Hypoph thalmichthysmolitrix, Cyprinus carpiol, Carassius auralus, Aristichthys nobilis.* The biomass of zooplankton feeding fishes is dominant.

Because there is a lack of competition for nutrients and energy, *Microcystis* gets all the ad-

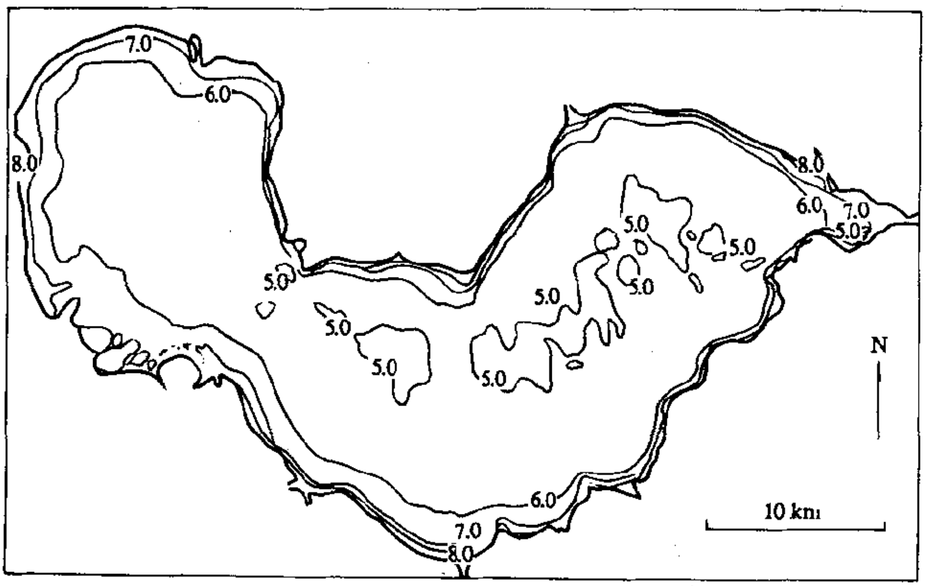

Fig. 2 The morphology of Chaohu Lake basin
The solid lines show the bed allevation (m) above the sea level. The average height of the lake water surface is 8.3 m above sea level

vantages. Zooplankton organisms which graze on phytoplankton can not grow well because there are too many secondary grazers and the disappearing littoral zone cannot provide enough ecotone space for zooplankton growth. In our research, we found that the macrophytes can inhibit the growth of phytoplankton by various ways; lack of littoral macrophytes certainly promotes the bloom of bluegreen algae.

Chemical reasons

Chemical factors play important roles in the aquatic ecosystem. They depend not only on the nutrient concentration but also on the general chemical compositions in the system.

Chaohu Lake water has the following chemical characteristics. The water often has a high pH valuc as consequence of algae development. According to our observation at Zhongmiao Station during 1987 and 1988, at 10 a.m. the pH value measured greater than 8.0 was often recorded. The highest value measured was 10.2 at a time with a algal bloom. Secondly, the lake water contains a low concentration of dissolved mineral matter. Because very small amounts of limestone are present in the watershed and the precipitation is high, the runoff water is generally soft. The dissolved solid in the lake water is 150 mg/L and the total hardness (calculated as $CaCO_3$) is 66 mg/L. Thirdly the lake water contains a high concentration of suspended solids, in a range of 40 – 1000 mg/L, because of the resuspension of sediments. The lake water contains stable colloid particles with a δ potential of 10 – 25 mV. The fourth is the oxidant condition in the whole water column. Since there is no stable stratification and the circulation is strong.

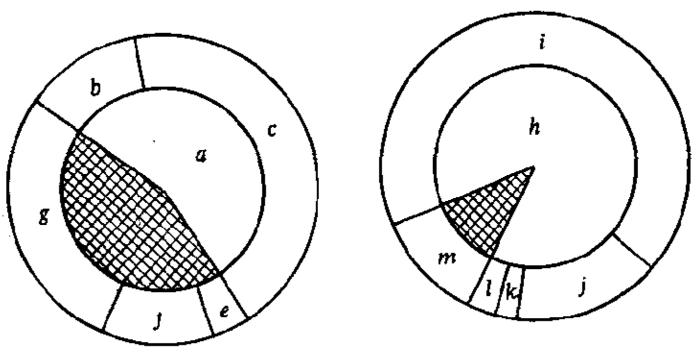

Fig. 3 The average percentage composition of nutrient input from Nanfei River into Chaohu Lake

a. Total soluble P, 56.4; b. Ortho-phosphate P, 12.6; c. Other forms of soluble P, 43.3; d. Total particulate P, 43.6; e. Pyrite P, 4.0; f. Bioavailable particulate P, 12.1; g. Other particulate P, 27.5; h. Total soluble N, 88.5; i. Ammonia N, 67.3; j. Nitrate N, 15.9; k. Nitrite N, 2.0; l. Organic soluble N, 3.3; m. Total particulate N, 11.5.

The water is usually saturated with oxygen. Some exceptions are the dense algal bloom events in which it shows an oversaturation in daytime and undersaturation at night.

The lake water is bicarbonate type in geochemistry, but contains a low concentration of bicarbonate (70 mg/L). Because of the high phytoplankton biomass and photosyntheses rate, the free carbon dioxide concentration in lake water is usually lower than the saturation-value, especially in the cases of algal bloom when the pH value is high.

Chaohu Lake water has a high concentration of nutrients especially of total phosphorus in a range of 0.05 – 0.20 mg/L and total nitrogen ranging of 0.6 – 2.6 mg/L. The average total phosphorus concentration measured in the lake water is 0.142 mg/L and the dissolved orthophosphate concentration is 0.026 mg/L. The sediment contains 0.058% phosphorus. Only dissolved orthophosphate is available directly to algae cells. If the water layer and the upper 20 cm sediment is considered as the ecosystem phosphorus reservoir, this lake system contains 111000 tons of phosphorus of which only 5.9 tons of the total, 0.054% can be directly taken in by plants.

Besides the nutrients originally in the lake, a large quantity of nutrients is carried into the lake from the catchment in various forms. About half of phosphorus enters the lake in dissolved form and the other is in suspended form. Nitrogen enters the lake mainly in dissolved ammonia form from the Nanfei River and Shiwuli River, and mainly in dissolved nitrate form from the other rivers. Fig. 3 shows the average nutrient compositions in water samples from the Nanfei River and Fig. 4 shows the nutrient composition from all the tributaries.

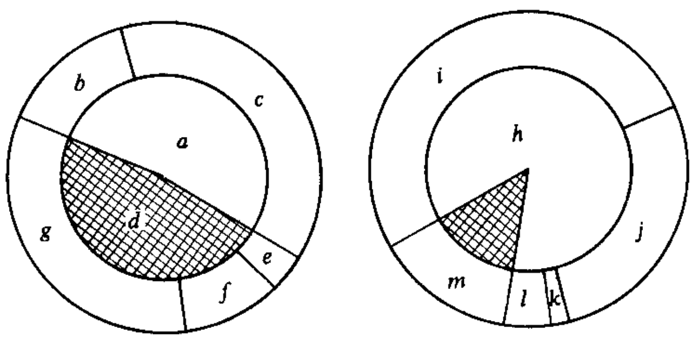

Fig. 4 The weighted average percentage composition of tributary nutrient inputs into Chaohu Lake

a. Total soluble P, 52.2; b. Ortho-phosphate P, 14.5; c. Other forms of soluble P, 37.7; d Total particulate P, 47.8; e. Pyrite P, 3.9; f. Bioavailable particulate P, 10.2; g. Other particulate P, 33.7; h. Total soluble N, 85.8; i. Ammonia N, 51.3; j. Nitrate N, 27.6; k. Nitrite N, 17.0; l. Organic soluble N, 5.0; m. Total particulate N, 14.2

The northwest part of Chaohu Lake is close to the estuaries of Nanfei River and Shiwuli River which carry large amount of ammonia into the lake. The lake water in that part contains a high concentration of ammonia. The high pH caused by eutrophication creates some ammonia in molecular form and the concentration can reach a toxic level to many aquatic organisms. This is probably another factor causing the dominance of *Microcystis*.

The high pH value of the lake water, low concentration of carbon dioxide and high concentration of phosphorus can be interpreted as the chemical factors causing the dominance of *Microcystis* in Chaohu Lake.

ANTHROPOGENIC FACTORS OF CHAOHU LAKE EUTROPHICATION

Although there are many natural factors for the eutrophication problem, the anthropogenic factors are believed to be the most important for causes. For thousands of years people have lived and carried out agricultural activities in the catchment and fishery has been developed for centuries. The lower part of the catchment has a name of "a rich land for fish and rice". The dense anthropogenic activities have changed the landscape of the watershed and changed the nutrient cycling in the ecosystem.

Many towns exist in the watershed for centuries and the urbanization in recent 40 years expands the cities in a high rate. In 1965–1988, Hefei City with an annual increase rate of 3.04%. In 1950, the city was a very small town with a population of only 100000 and it expanded to about ten times since then. In 1988 the city population was 0.95 million. The total wastewater discharge was 139 million tons in which 111 million tons was from industry. All domestic sewage is untreated and only a small portion of industrial water is simply treated. The other towns Chaohu City, Feidong, Feixi, Shucheng and Lujiang have the same trend. Besides, hundreds of villages are by the side of the lake and its tributaries. These point sources export large quantity of nutrients to their receiving water— Chaohu Lake and make the important contribution of its eutrophication.

The virgin forest in this region was destroyed in the history. The secondary forest has an area of 706 km^2 in the catchment and the coverage is only 6.8%. Most of the forest is composed of young trees. In recent 40 years, there have been three large scale deforesting activities due to mistakes in policies. In Shucheng County in upstream of the Hangfu River, 14000 hectares of forest had been turned to agricultural land up to 1983 in which 64% was on slopes of 21 degree or more. Such activities have caused severe soil erosion especially in the west part of the catchment where mountain soil has loose texture and land is on steep slopes. The most severe case in Shucheng County shows an erosion depth of 35 mm/a in one plot. It is estimated that 56.9% of the land in the catchment have the problem of erosion and 2 million tons of soil is lost annually. Other projects such as mining and construction also caused soil erosion in the sites.

Chaohu Lake catchment is a base to export grain to other provinces. The heavy impact has made farmers apply large dose of fertilizers and pesticides. The average fertilizer usage has been increased from 7.5 kg/ha in the 1955 to more than 1200 kg/ha in 1980s. The dose is still increasing by years. The major fertilizer used in this area are ammonium bicarbonate, urea, perphosphate and N-P composite fertilizer. The land use for agriculture is 5.24 million hectares in the catchment. Since the fertilizer usage is more than the need, a large portion is lost by vaporization to atmosphere or runoff to the acceptive water.

In 1959, two water gates were built on the Yuxi River downstream of Chaohu Lake to raise the water level in winter and spring, but the lake itself has become lagoon-type and artificially controlled.

Wastewater discharge to the lake, soil erosion, fertilizer runoff and irrational management of water gate are major anthropogenic impacts to Chaohu Lake for its deteriorated environment. Fig. 5 shows the interrelationships of factors affecting the metabolism of Chaohu Lake.

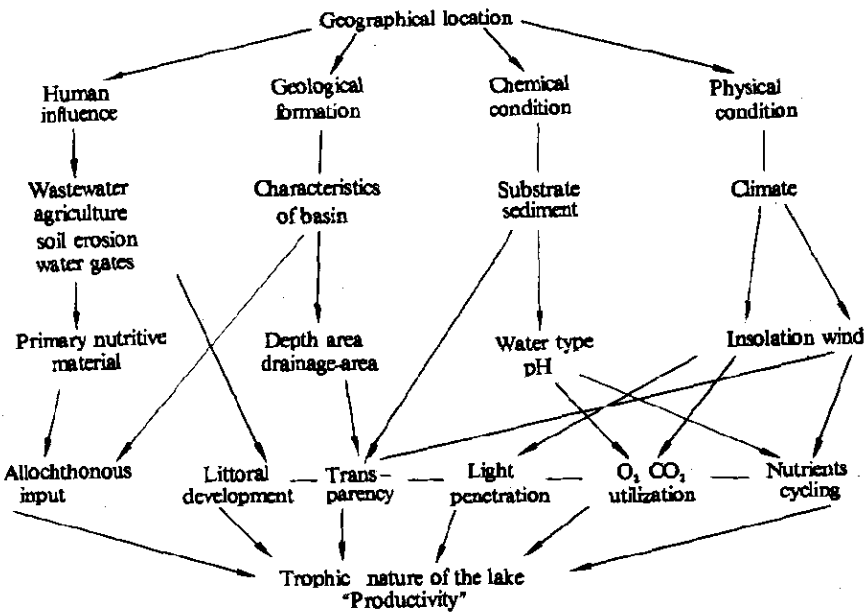

Fig. 5 Relationships of factors affecting the metabolism of Chaohu Lake

LIMITING FACTORS OF ALGAL GROWTH

When a water body's trophic state is concerned, one question is the limiting factor of algal growth in this water. For most of lacustrine and marine ecosystems, bio-available phosphorus is the limiting factor for algal growth. This is the result for most lakes in Europe and North America in which the stratification exists, water is less turbid and usually in lower trophic state. Therefore, limiting the input of the "macro-nutrient" phosphorus represents a primary eutrophication control option.

Sun (1990) reported the analytical results of the dissolved inorganic phosphorus, dissolved organic phosphorus and residue phosphorus content in fresh *Microcystis* samples collected from Chaohu Lake in September 1987 and October 1988. The results show that 20.7% of the total phosphorus in algal body was dissolved inorganic phosphorus in September samples and 30.9% of the total was dissolved inorganic phosphorus in October samples. Literature evidence indicates that if phosphorus is the limiting factor for algal growth, the dissolved inorganic phosphorus taken in by the phytoplankton will be quickly converted to organic and residue phosphorus in the algae cells and there will be no or very low content of dissolved inorganic phosphorus (SRP) in fresh algae samples.

In our enclosure experiments, the phosphorus threshold for algal (mainly *Microcystis*) growth was detected as 0.019 mg SRP/L (Lan, 1992), which was lower than average dissolved orthophosphate concentration 0.026 mg SRP/L in Chaohu Lake measured in 1987—1988 period. Furthermore, since there is often large algal biomass in the lake water, the actual bioavailable phosphorus concentration in the lake water is much higher than 0.026 mg/L. The lake water has a high soluble total phosphorus concentration 0.049 mg/L which is probably the bioavailable part of phosphorus in water and is much higher than the threshold concentration. The lake is generally oversaturated with phosphorus.

These evidences indicate that phosphorus and other nutrients are not always the limiting factors for algal growth in the case of Chaohu Lake. The reason is too high concentrations of nutrients in the aquatic ecosystem. Therefore other factors such as light and temperature can limit the algal growth in different periods alternatively. It was found that the light intensity in greater depth of the lake was quite low because of the high turbidity. The light thus inhibits the growth of algae in greater depth and has discrimination for non-buoyant algae. When there is turbulence by wind and *Microcystis* is also turned to the lower part, the light limitation then takes place for all algae including *Microcystis*.

Chaohu Lake is oversaturated with phosphorus to algal development from the viewpoint of nutrient in most of the time and other environmental factors often play the role of limiting algal growth. Besides, the lake has a low depth and the nutrient release from the sediment in rapid. These create difficult situations for the policy makers concerning Chaohu Lake management. It is almost impossible to control other factors such as light, carbon and temperature. One way to solve this problem is to reduce the phosphorus load in large proportion so that the phosphorus limiting condition can occur (Bernhardt, 1987). Fig. 6 shows a simplified diagram of biomass response in the lake followed by reducing P-load. This of course further increases the cost of treatment and takes longer time for lake recovery after the treatment.

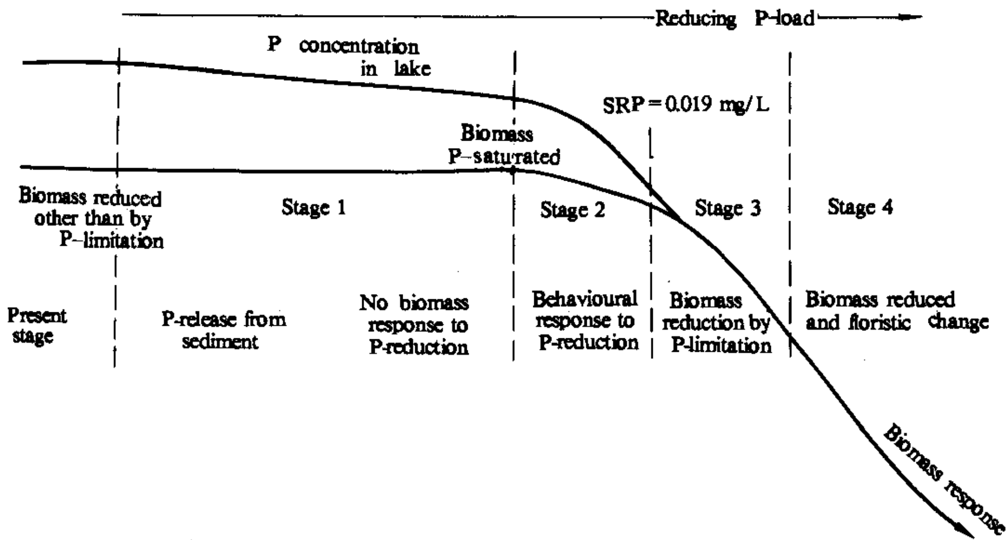

Fig. 6 A simplified diagram of biomass response in lakes following the practice of P-load reduction, modified from Reynolds

AN ECOLOGICAL VICIOUS CYCLE

The Yuxi River - Chaohu Lake water can be roughly divided into five subsystems: agricultural subsystem, city subsystem, subsystem of upstream and ponds, lake subsystem and Yuxi River downstream subsystem. Before 1959, the natural matter and energy exchange strengthened the relationships among the subsystems. Although there was algal bloom record down to the end of last century, but the scale and frequency was rather small and it did not cause big problems. The matters from the catchment enter the lake through tributaries. There were flows and backflows among Chaohu Lake, the Yuxi River downstream and the Yangtze River. According to hydrological data, the average runoff from Chaohu Lake and the upstream tributaries was 3030 million m^3/a and the backflow from the Yangtze River used to be 1360 m^3/a before 1959. The ratio was 1 : 0.45. Because great amount of water flew into the Yangtze River in springs, the lake water level became rather low and large area of littoral land appeared along the lake shore which created a nice biotope for a variety of macrophyte and other littoral organisms. At those years, the littoral area occupied about 150 km^2— one fifth of the total lake surface area. Chaohu Lake at that period it was on a natural eutrophication process-decaying by increased littoral zone area, decreased lake surface, development of productivity and accumulation of organic matter and silt.

Since the gates were built at that time, the average runoff from the upstream lake has been 3490 m^3/a, and the backflow 160 m^3/a with a ratio of 1: 0.05. The decrease of water exchange make Chaohu Lake a semiclosed lagoon. Meanwhile several large reservoirs and many ponds with various sizes were constructed in the upstream of the lake and the relationship between agricultural subsystem and the lake is also controlled by human activities. Thus the entire water body has almost become an artificial impoundment.

People often manage the artificial system according to their own ideas and short term benefits, which is sometimes against the law of the nature and causes an ecological vicious cycle. In the past 30 years, the water level is controlled only according to the requirement of boat transportation and agricultural irrigation. The water level is now much higher than the natural level. In 1950s, the spring water level was about 6.2 m sea level and large area of littoral zone was dry in springs. This was in favor of the sprouting of the various macrophyte. But during 1962 to 1983 after the water gates were built, there were 8 years in which the spring water level topped 7.8 m and the littoral zone almost disappeared with the majority of macrophyte unable to sprout and killed. The landscape of vigorous emersed vegetation disappeared. Another consequence of the gates is to block the exchange of aquatic organisms between the Yangtze River and the lake through the exchange of water. There used to be 460 – 1500 million m^3/a flow from the Yangtze River and it was estimated that there were about 100 fish fries per cubic meter in spring river water which produced Chaohu Lake large quantity of silver carp and other economic fishes. After the gates were built, the biomass of silver carp and migrating fish declined tremendously. Although there are fish migrating channels on the water gates they are often blocked. Besides, there are two chemical plants on each sides of Yuxi River just downstream of the Chaohu water gate and the wastewater discharges into the river directly. The diffusion and degradation rates are very low by the closed gate and the pollutant ammonia can accumulate to reach a high concentration up to 15 mg/L which was toxic to many organisms. This has greatly reduced the potentialities of fishery production in Chaohu Lake (Yan, 1987).

The high turbidity of the lake water was indirectly enhanced by the gate construction. It is known that emersed and submersed plants can fix the underneath sediment and reduce the sediment resuspension. Without the protection of macrophyte, the rate of sediment resuspension and bank erosion is greater than mud the siltation in most shore areas. The average depth of the lake is less than 3 meters, the large resuspension rate causes evenness of the lake bottom, i. e., to erode in the shallow and deposit in the deep. In the lake, shipping lanes have to be dredged every a few years and mud be transported to the surrounding areas, but the wave scour and sediment resuspension just work in an opposite way to fill the lanes and make the dredge a waste of labor and energy.

Hefei City is the most important point source for nutrient export from the catchment. Being the province capital, it is political, economical. educational and cultural center of the province and is developing rapidly in recent decades. The investigation shown in 1988 the wastewater discharge was 139 million tons in which 111 million tons was from industries and 29 million tons was domestic sewage (Anhui Statistics Bureau, 1989). The wastewater is discharged into Nanfei River and enters the lake. There is no treatment for sewage and only a small portion of industrial wastewater is treated in plant. According to chemical analysis, the total P and N concentration in Nanfei River are about four times of the weighted average of other rivers. The calculation shows that the point sources of pollution contribute nearly a half of nutrient input to the lake.

The mouths of Nanfei River and Shiwuli River are located in the northwest part of the lake and are very close to the water plant for the city's drinking water supply. The pollution has caused great problems to the water plant and reduced the drinking water quality in the city. Several accidents happened in the plant by the water pollution and caused the city suffer from water shortage. The worst case happened during September 28 to October 4, 1988 and one third of the city was supplied either with no water or with stinking water. The health of citizens is threatened and tremendous economic loss was resulted. The water supply shortage caused by pollution has become the limiting factor for the development of regional economy.

The important non- point nutrient sources are soil erosion and fertilizer loss while the contribution from atmospheric precipitation and forest is rather small (Jiang, 1988). Slight, medium and serious erosion areas occupy 45.5, 14.3 and 0.8% of the total catchment area respectively. The soil erosion mainly takes place in dry farming lands, low mountain areas and hillocks with poor vegetation in the upstream catchment. Part of the soil and nutrient trapped by the ponds, reservoirs and upstream beds and some nutrient can return to the agroecosystem. This mechanism thus reduces nonpoint pollution. Rice is the main agricultural product in the catchment and fertilizer application per unit area is high. Nitrogen runoff is large from rice fields. For phosphorus load, early rice, which harvests in summer, is not an important contributor but late rice harvesting in Autumn greatly contributes to the water system. Rice field is a nutrient source when precipitation is after fertilizer application and there is runoff discharge or overflowing from the field. When there is no overflow, the rice field acts as a sink to accept nutrients from upland runoff. Besides allochthonous load of nutrients, Chaohu Lake has sediment with high nutrient content. The physical factors, such as small depth and strong wind, make the water and sediment mix frequently and the nutrient elements are liberated quickly from mud. This internal source is also important in the process of eutrophication.

INTEGRATED TREATMENT OF THE SYSTEM TO CONTROL THE EUTROPHICATION

The eco-environmental problem from a very complicated diagram (Fig. 7). The environmental quality is still declining and this is threatening the sustainable development for the future. Human's most urgent task is to turn this vicious cycle into a good succession. Many actions should be taken, among them the priority is to make a practical management strategy based on economic and scientific optimization.

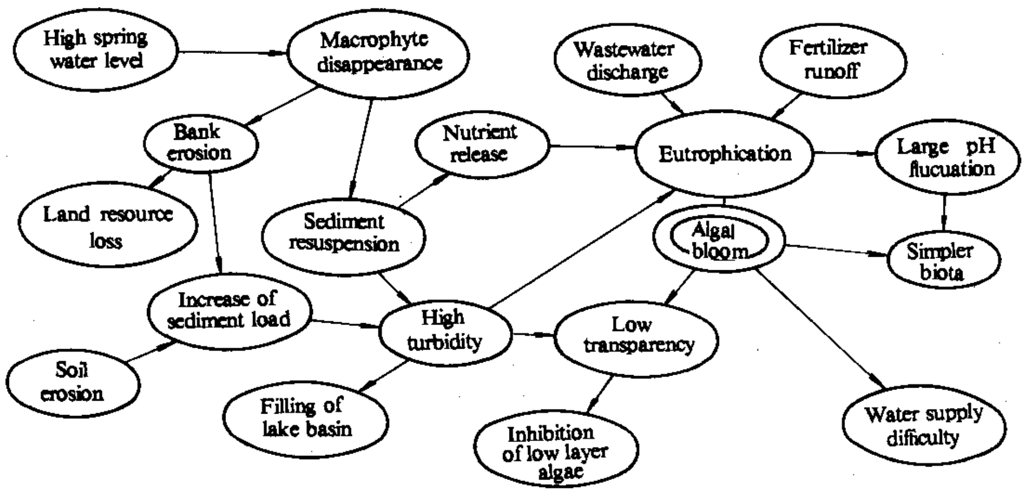

Fig. 7 The interactions of environmental problems in Chaohu Lake

The rapid industrial development and urbanization has a great impact on the environment and natural resources. In the province development strategy, the province should develop many medium and small sized economic centers instead of focusing investment on Hefei and its surrounding area so that the pollution impact and resource tension will be reduced. Then, the economy of Anhui Province will develop in more balanced basis and the environment will be better protected and can support the development of the human society.

It is necessary to set an adequate water management system as to the hydraulic control of the lake. The benefit of all economic-ecological functions should be taken account of several years ago, scientists in Anhui Province raised a proposal of "ecological water level" to keep the level suitable for the requirement of a healthy ecosystem as well as the requirement of boat transportation, agricultural irrigation and city water supply (Anhui Institute for Environmental Protection, 1986). They proposed that in February and March, the water level should be in 7.5 m level, which is higher than 6.2 m level before water gates construction, to sprout submersed and emersed plants and not to impair transportation and irrigation. In April, the water level would be raised by controlling the water gates, following the growth of macrophyte and in July and August the water level would kept in 10 – 11 m level. This is a correct proposal for the ecosystem as well as for the economy. If the macrophyte vegetation can recover in large littoral area, more mud will be deposited in this zone. Lake shore and boat lane will better protected. This biota-biotope system will provide a hibitat for different algae, zooplankton and fishes and will serve as a refuge for some species.

For the implementation of this proposal, several consequences have to be considered. A too small littoral cannot inhibit *Microcystis* growth and a too big littoral will probably accelerate the filling of the lake. The other consequences are how to keep the boat lane deep enough, to dispose the dredged material, the security against the possible recovery of perished locust, blood floke and its host snail, and serious droughts happening every ten years and so on. A further interdisciplinary research should be carried out to prevent bad consequences.

When the spring water level is low enough, the Yangtze River water can flow back into Chaohu Lake through Yuxi River, which will bring millions of fries and migrating organisms. In addition to artificial hatching, it is possible to recover a good fish community to convert primary productivity to better aquaculture products.

Eutrophication is the key problem for Chaohu Lake. To reduce the trophic state is a fundamental settle of the problem (Bernhardt, 1990). According to the phosphorus threshold for algal growth (0.019 mg P/L) and the present soluble reactive phosphorus concentration in the lake water (0.026 mg/L), the phosphorus concentration should first be decreased 27% to reach the threshold level. Then considering the high concentration in the sediment, the low depth and a high soluble total phosphorus concentration in the lake water, the nutrient phosphorus load has to be cut much more than 27%. To reduce the nutrient load from the point sources is always more economic and effective than from non-point sources. To built a large scale secondary wastewater treatment plant or several medium-sized plants is a necessary way not only for saving the lake but also for the drinking water quality and the sustainable development of the region. The effluent of the secondary treatment plants has to be treated to remove most of the nutrient since the receiving water in such an important lake and a well designed land treatment system is probably a good choice to achieve this purpose. Before the secondary treatment plants are constructed. Some temporal settlements have to be considered such as to dredge Nanfei River before the flood season and to dispose the nutrient-rich sediment out of the water system as a good soil conditioner for agriculture; to construct settling oxidization reservoirs in some low land for wastewater; to diverse the wastewater out of the Chaohu Lake catchment; to set land treatment systems to remove pollutants; to built primary waste water treatment plants. These economical way can reduce phosphorus and nitrogen in large scale and need lower capital expenditure and maintenance cost and they are much better than doing nothing. In the next stage, it is needed to build large-scaled tertiary treatment plants or chemical phosphorus elimination facilities to remove nutrients to a great extent.

Non-point pollution is more difficult to control. In the history, many ponds were built in the catchment for farmland irrigation and they are found very effective to trap nutrients and sediments which then recycle in the terrestrial ecosystem. In recent decades, the development of large-scaled reservoirs and modern irrigation networks have reduced the importance of the ponds in agriculture and some ponds have been or will be filled with eroded solids. We found non-point source pollution can be effectively treated by the well scattered multipond system and suggest that human should protect this good system to reduce water and nutrient runoff.

Farmer near Chaohu Lake used to collect thick algal bloom for fertilizer. This is an excellent way to reduce *Microcystis* biomass and to uptake nutrients from the lake. In recent years, because labor cost increases and chemical fertilizer supply is abundant, more farmers depend on chemical fertilizer than fermented algae. More communication is needed to tell the farmers on keeping their good tradition. The state should aid to invent modern machinery for algae collection, treatment and commercialization of algae fertilizer.

Now the water quality of Chaohu Lake limits the regional economic development and the economy is not able to provide enough investment to treat the pollution sources. One way to search out of the cycle is to make an overall strategy analysis. According to pollution sources and treatment methods, a priority order should be arranged with the costbenefit effectiveness. Chaohu Lake and its watershed is a complicated system where many ecological problems have accumulated for years. The settlement of any problems is a difficult task of systematic engineering. Now, these problems, especially the water supply, have become more and more the limiting factors of the regional economic development and human being has to do something to improve the environment for the nature as well as for themselves.

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(Received October 19, 1991)