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The New Strategy for Improving the Aqua-Ecological Environment in Taihu Lake Basin, China--"How can we solve the problem of lack of qualified water and deterioration of environment and natural resources in Taihu Lake Basin?"*

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Abstract: *Taihu Lake is one of the famous five great freshwater lakes in China. Taihu Lake Basin (TLB) is a densely populated and economic developed area in China. The surface water quality in TLB was deteriorated from I-II grade in the history to IV-V grade at present. To develop a series of technology of most cost-effective and achievable for improving environment in a local water area of most sensitive for society and improving water quality for more and more areas step by step is the key point of the new strategy. Except the measures for reducing the industrial and domestic pollution load to the lake, some research topics are suggested to be emphasized*
Keywords: *Strategy for improving aqua-eco-environment, Taihu Lake*

Taihu Lake is one of the famous five great freshwater lakes in China with an water area of 2338 km^2, mean depth of 1.9 m. Taihu Lake Basin (TLB) covered 36 500 km^2 with a population density of 980 km^{-2} and total population of 36 million. There are 1.77 million hm^2 cultivated land in this area accounting for 1.7 % of whole China, but the agricultural and industrial production value make up 1/7 of that in whole China. This area is eulogized as an area with green mountains and clear waters, an area rich in fishes and rice in the long history. But recently, the surface waters in TLB suffers pollution and environmental progressive deterioration increasing with development of population and economic growth. Being on the position of posses the nature, the mankind has discovered that we are now on the catastrophic boundary of ecosystem. The surface water ecosystem has been destroyed into "desert water" from local area to most part of the

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catchment in many rapid developing economic regions. The submerged plants and benthos disappeared, algae bloom appears more and more frequently, the water quality has deteriorated from I-II grade in the history to IV-V grade at the present, there are no qualified drinking water sources. The lakes and rivers are in danger. How can we save our lakes and rivers from progressive environmental deterioration? This is an extremely serious problem we are faced with.

1. Pollution sources and the important approaches for improving water quality in Taihu Lake

Tab 1.1 Total pollutant loading in Taihu Lake Basin (1994)

Pollution source		Wastewater, 10^4 t · a^{-1}	COD_{cr}, t · a^{-1} (%)	TN, t · a^{-1} (%)	TP, t · a^{-1} (%)
Industry wastewater		53 901	111 061(39)	12 544(16)	591(10)
Domestic Wastewater		32 290	119 029(42)	19 948(25)	3 394(60)
Rural pollution	Agricultural	128 373		18 355	164
	Domestic.	15 671	11 377	1 896	433
	Animal	1 203	16 761	9 591	255
	Sub-total	145 247	28 138(10)	29 842(38)	852(15)
Fishery		83 774	(0)	13 95(17)	533(9)
Domestic in coastal zone		216	17(0)	21(0)	3(0)
Rainfall		3 341	23 595(8)	2 760(4)	60(1)
Solid precipitation				421(0)	33(1)
Ships			164(0)	22(0)	2(0)
Erosion				800(1)	192(3)
Total		318 769	282 404	79 552	5 660

Tab 1.2 Total pollutant loading to Taihu Lake (1994)

Pollution source	COD_{cr}, t · a^{-1}	TN, t · a^{-1}	TP, t · a^{-1}
Inflow rivers	107 057	26 107	1 361
Rainfall	23 595	2 760	60
Solid precipitation		421	33
Erosion		800	192
Domestic in coastal zone	417	21	3
Ships	164	22	2
Fishery in nets		505	100
Total	131 233	30 635	1 751

The main pollutants in TLB are COD_{cr} 282,404 t · a^{-1}, TN 79 552 t · a^{-1}, TP 5 660 t · a^{-1} in 1994 (Tab. 1.1). The COD pollution has the major sources from domestic and industrial wastewater, the TN pollution has abundant sources from agriculture, domestic, fishery and industry wastewater, but the TP pollution has the major source from domestic wastewater.

The total pollutant loading to Taihu Lake is COD_{cr} 131 233 t · a^{-1}, TN 30 635 t · a^{-1} and TP1 751

$t \cdot a^{-1}$. The detail information is shown in Tab. 1.2. As it is shown in Tab. 1.2, the major pollutant loading to Taihu Lake is from rivers. The contribution of COD and TN loading from rainfall could not be omitted both for Taihu Lake and its basin.

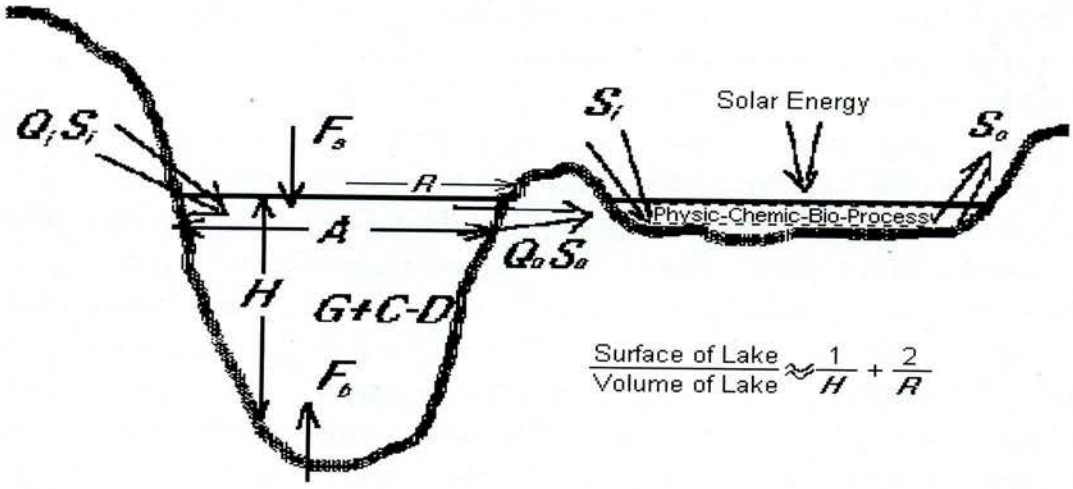


Fig.1 Diagram of inorganic nutrients balance in a lake.

To decrease the pollution loading to the lake is essential for improving water quality in Taihu Lake. Many efforts are concentrated on controlling the pollution from industrial wastewater. Every industrial objects are requested to release their wastewater with concentration of pollutants lower than that of state standard. Those factories which could not reconstructed to meet the state standard for environmental protection should be closed. All the new industrial constructions should be approved by the environment protection authorities. For collecting and treating the domestic wastewater and separating it from rainfall, it needs a big budget for such high densely populated region. Beside the financial difficulty, there are a lot of technological and management difficulties for agricultural pollution and rainfall pollution. Therefore, in the nearest future, the situation of pollutant loading to the lake could not be expected to be improved rapidly.

In addition, the internal pollution and rainfall pollution in Taihu Lake plays an important role. According to the mass balance equation, the time variation process of the mean concentration of an inorganic nutrient S may be described by the following equation (Fig. 1):

$$\frac{\partial AHS}{\partial t} = Q_i S_i - Q_o S_o + A(F_s + F_b) - AH(G + C - D) \qquad (1)$$

or

$$\frac{\partial S}{\partial t} = \frac{1}{H}\left[\frac{Q_i S_i - Q_o S_o}{A} + F_s + F_b\right] - (G + C - D) \qquad (2)$$

$$\frac{\partial S}{\partial t} = \frac{S_i}{T}\left(1 - \frac{Q_o S_o}{A_i S_i}\right) + \frac{F_s + F_b}{H} - (G + C - D),\ T = \frac{AH}{Q_i} \qquad (3)$$

where A, H, Q are the surface area, mean depth and inflow of the lake; the subscript i and o, the inflow and outflow, separately; T, the resident time of lake water; F_s, F_b, the fluxes of S into water from air-water and water-bottom interfaces separately; G, C, D, the variation of S caused by growth of biomass, chemical processes, and decomposition, separately.

From above equations, for improving water quality ($\partial S / \partial t < 0$), to decrease the nutrients load to a lake is essential, but for large shallow lakes with a long resident time, the elements of F_s, F_b and G, C, D have great importance. For a Netherlands Loosdrecht lakes the external phosphorus load was been decreasing substan-tially since 1984, but the measures taken to counteract eutrophication were not successful (Van Liere, L., *et al.,* 1992). For shallow lakes the release of phosphorus and other nutrients from lake sediment and the resuspension of detritus and sediments from bottom obviously (Keizer, P., *et al.,* 1992; Wu, J., *et al.,* 1990). These process are strengthened by storms and wind waves (Pu, P., *et al.,* 1990). The turbidity changes rapidly in shallow lakes. Fisheries management for controlling algal bloom has resulted in a considerable improvement of water transparency in small lakes (Meijer, M.-L, *et al.,* 1989). Experiments on a middle scale lakes, have so far not been successful (Van Donk, E. M. P., *et al.,* 1990; Chen, S., 1990). The dredging measures may be used for improving the transparency in small lakes (Van der Does, J., *et al.,* 1992), and meet a great deal of technical, financial, and even principle difficulties for middle and large shallow lakes, such as in Lakes Taihu, Chaohu and Dianchi. The flushing measures have been tested in Lake Xihu (Hangzhou, China) with an area of 5.6 km^2 and mean depth of 1.6 m. The water quality improved just in a limited inlet region and in a period of days (Wu, J., *et al.,* 1990).

2. Main points of proposed strategy

Taking all the difficulties into consideration, to solve the problem of qualified water supply for shallow eutrophic lakes such as Lake Taihu, whole lake restoration can only be a long-term objective. In the short-term however, to develop a series of technology for improving environment in a local area to meet the urgent need of the society is possible.

Dissolving or suspending some matters into water is the natural pollution process with increase of entropy. Oppositely, concen-trating and enriching the dissolved and suspended matters for harnessing environ-ments is the process for purifying water with a big consumption of energy and financial input. Therefore, it needs to find the approaches and technologies for purifying water quality with low cost, but high efficiency for improving environment and output of utilizable resources.

The main topics of proposed strategy are:

* Reducing the domestic, industrial and agricultural waste water by economic and multi-level use of water, enhancing policy and technology management;

* Harnessing the water quality at different level of pollution, starting from drinking raw water (Pu, 1993) and pollution release point;

* Enhancing the capability of self-purification of the water body as the key measure, transforming the polluted water body into base for water purification;

* Harnessing the surface water in TLB, starting from local area to larger areas and whole of the basin by local artificial ecosystems with high efficiency of water quality purification;

* Harnessing Taihu Lake with different approaches in different functional districts: Restoration historical landscape where there are submerged plants; Purifying water in estuary of main pollution loading inlets by using physico-ecological engineering (Pu, 1993); Collecting algae by using "Jellyfish Engineering" (Pu, 1995);

* Developing the water quality harnessing technologies with economic benefits, converting the wastes into valuables and transforming the environment undertaking of economic input into the Bio-Environmental Enterprise (BEE)--harnessing environment with economic benefits as the spark technology, which may be disseminated, like "oases in desert water body", in TLB widely.

3. Key point of new strategy and main research topics

Among them, to develop a series of technology of most cost-effective and achievable for improving environment in a local water area of most sensitive for society and improving water quality for more and more areas step by step is the key point of the new strategy. Except the measures for reducing the industrial and domestic pollution load to the lake, the following research topics are suggested to be emphasized in Taihu Lake Basin (TLB):

A) To develop the technology for supplying qualified raw water for drinking by using treated rainwater in rural area and Physico-Ecological Engineering (PEEN; PU, 1993, 1997, 1998) for improving water quality in intake areas of drinking water plants in TLB;

Almost all the surface waters are polluted in TLB. Overtaking underground water leads sinkage of land in many regions of TLB. The lack of qualified drinking water is the most urgent problem, facing in this area. Supplying qualified drinking water can be realized by using treated rainwater in rural area and PEEN for purifying raw water of waterworks.

A1. Using rain water in rural area. In rural area of TLB there are no other qualified surface water for drinking, except the rain water, as the clearest surface water sources. Every family has a separate house, and the roofs of the farmer's houses may be constructed as the collectors of rain water. After a preliminary filtration and other treatment, the rain water may be stored in an underground pottery made pipe system connecting with some houses/or a village for advanced drinking water treatment. TLB is the capital of pottery in China, the local resources and handicraft technology may be used. The research subjects are:

A1.1--Rain water collector techno-logy;

A1.2--Underground pottery made storage pipe system;

A1.3--Drinking water advanced treatment equipment and technology.

A2. PEEN in intake area of Drinking Water Supply Plant (DWSP). It is impossible to improve water quality for whole of the Taihu Lake at the present, but dozens million people are waiting for qualified drinking water. The PEEN is an artificial ecosystem with high efficiency of purifying water quality and enhanced output of aqua-products (PU, P., *et al.,* 1993, 1997, 1998). The principles for purifying water quality are shown in Fig. 2. They are:

1) Physical-biological membrane (PBM) for control the side exchange rate of mass-energy-momentum (MEM) between PEEN and its surrounding and protection of the hydro-environment and ecosystem in PEE. The fact that PEEN needs PBM is similar that any living cell needs cell membrane or any plant and animal need skin.

2) Frame engineering for installing physical-biological measures including the area, the ways and position of inflow, the current control, the carriers of biological population, etc.

3) To decrease both the mean concentration of pollutants and the frequency of high pollutant concentration by choosing the ways inflow, averaging the water mass in space and time and enhance the mixing process out of PEEN.

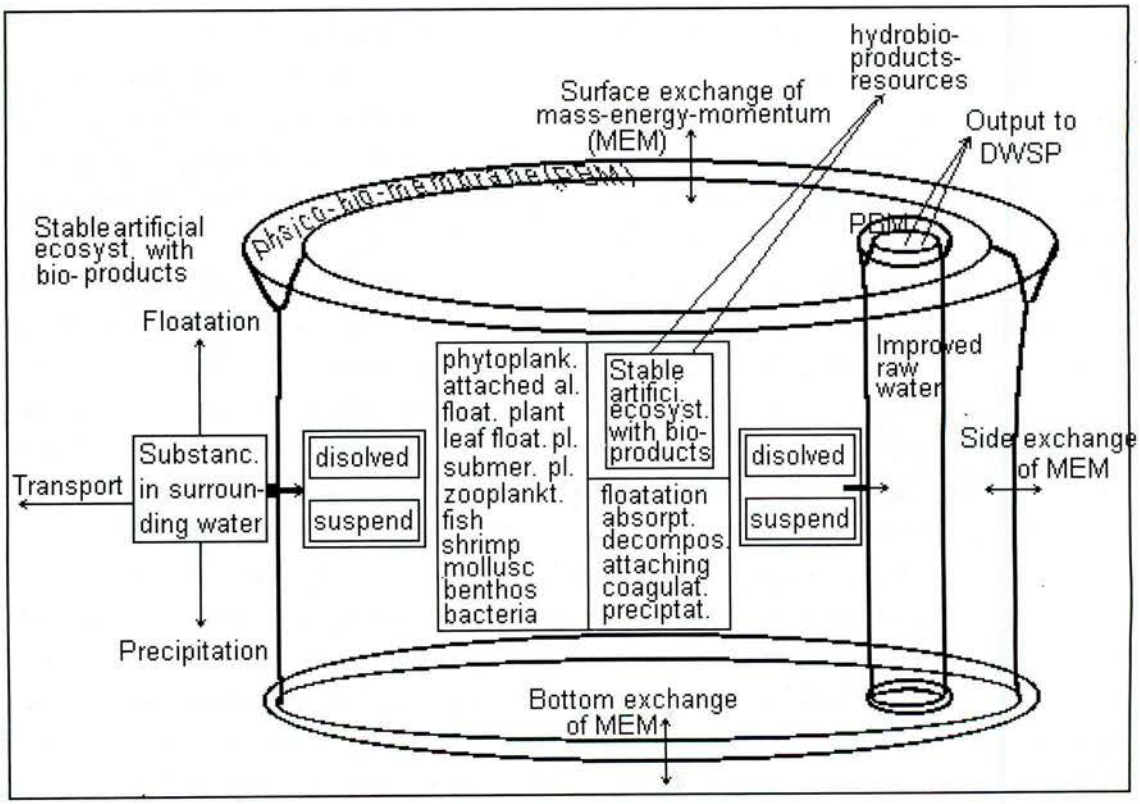


Fig. 2 Diagram of the principles for purifying water by PEEN

4) Filtration. The water quality may be improved obviously in PEEN by two times filtration. The key technologies are to offer a sufficient and sustainable volume of output raw drinking water (Pu, *et*

al., 1993).

5) Biological purification. Water quality is improved in PEEN mainly by precipitation, attaching, coagulation, absorption, decomposition, predation, etc. Optimization of the ecosystem structure in PEEN was realized by physical measures and changing and controlling the biological population. The management efforts were emphasised onto improving transparency, reducing the concentration of phytoplankton, ammonia nitrogen, nitrite and phosphate, and the colour degree. Some artificial carriers were used for attached algae and snails. Various species of floating plant, leave floating plant, submerged plant[such as waterhyacinth (*Eichhornia crassipes Solms*), Water Peanut (*Alternanthera philoxeroides Griseb*), *Ipomoea aquatica*, *Hydrocharis dubia (BL.)* Backer, *Salvinia nalans (L.)* All., *Elodia, Potomogeton crispus L., Myriophyllum spicatum L., Trapa natans L., Lemna mnor L. etc.*, shrimp, snail and other mollusc were cultured and tested in PEEN for purifying water (Pu, P. *et al.*, 1995-4). The dominated species should be changed during the year for gaining the maximum effects on purifying water. The related bacteria communities are of great importance in purifying water quality.

6) Restraining the release of pollutants from sediment and promoting denitrification in sediment. The key measure should be to restore the submerged plants cover with different dominate populations and all its related community complex including some detritivorous animals in whole of the year.

B) To improve farmland management: To develop the technology for reducing erosion and nutrients lost from cultivated lands, reducing the probability and intensity of flood hazards, and developing three-dimensional integrated agriculture in TLB by using construction of underground multi-functional tunnel-reservoir systems, and improving integrated management measures of water-fertilizer in paddy fields;

The most part of TN and sediment loading and great deal of TP loading into surface water in TLB come from the farmland, especially during flood period. The flood hazards usually occur in rainy season. If we may store the heavy rainfall in the fields (most of them are paddy fields in TLB), the erosion and nutrients lost from farmlands, the probability and intensity of flood hazards will be gradually reduced. Therefore, the technology for reducing erosion and nutrients lost from cultivated lands, for reducing the probability and intensity of flood hazards, and a 3-dimensional integrated eco-agriculture for increasing productivity in TLB should be developed and the following subjects are proposed:

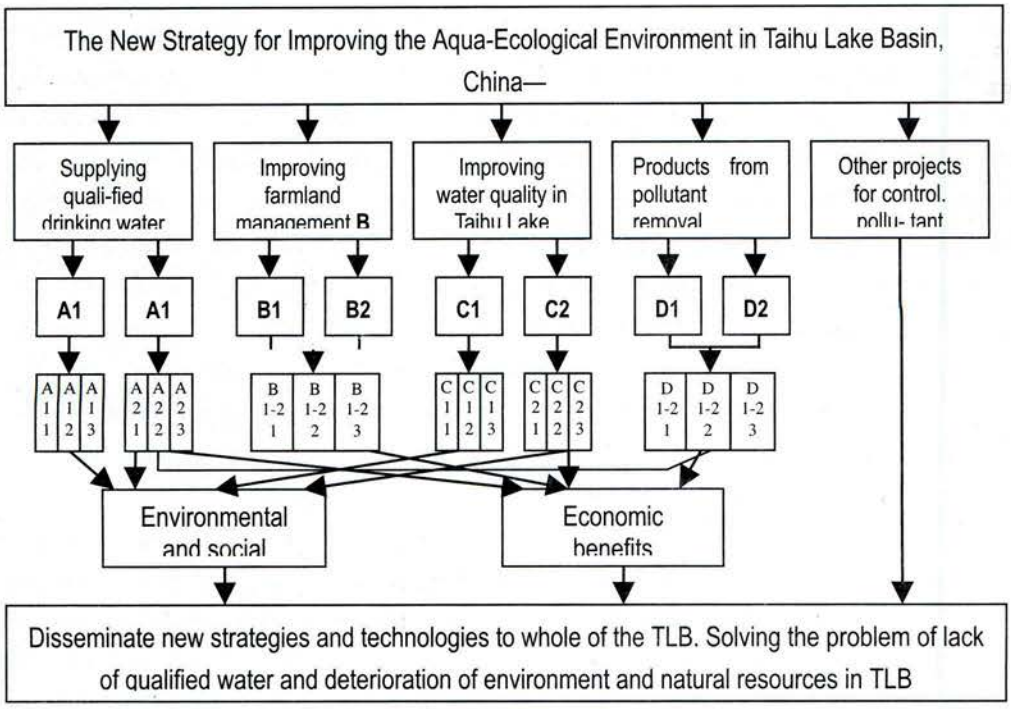
B1. Construction of underground multi-functional tunnel-reservoir systems in paddy field;

B2. Improvement of integrated management measures of water-fertiliser in paddy field. The work contents are:

B2-2.1 Reducing erosion, nutrients lost from farmland; including reduction of application rate of N-fertiliser, and improving application method of N-fertiliser in flood rice field;

B2-2.2 Reducing probability and intensity of flood hazards;

B2-2.3 Developing 3-dimensional integrated eco-agriculture.



Using rain water in rural area

PEEN in intake area of DWSP

Constr. underground multi-function tunnel reservoir systems

Improving integrated manag. measures of water-supply &

Manag. measures & policy lead to reduce pollution loading to lake

Construction of suitable PEENs in different regions in TBA

Foodstuffs for man & livestock from non-toxic biomass in PEEN

Non-food products from toxic aquatic products in PEEN

A1.1 Rain water collector technology
A1.2 Pottery made storage pipe
A1.3 Drinking water treatment equipment
A2.1 Supplying qualified raw water for DWSP
A2.2 Enhanced output of aqua-products, formation of BEEN
A2.3 Reducing consume of energy, materials and labor

B1-2.1 Reducing erosion, nutrients lost from farmlands
B1-2.2 Reducing probability and intensity of flood hazards
B1-2.3 Developing 3-demensional integrated eco-agriculture

C1.1 Harnessing water quality from local to large areas
C1.2 Policies of water cost and pollution water release cost
C1.3 Research funds for clear indust. production & pollution
C2.1 Recovery of macrophytes where they were there
C2.2 "Jellyfish Engineering" for collecting algae by wind energy

D1-2.1 Technology for concentration & enrichment of algae
D1-2.2 Processing technologies for different aqua-prod**strategy**
D1-2.3 Technologies for culture new species for foodstuffs

Fig. 3 Diagram of main research topics for new

C) To improve water quality in Taihu Lake by enhanced management measures, construction of suitable PEENs in different regions of the lake and enhanced output of hydrobiological products from PEEN;

The main measures are:

C1. Management measures and policies lead to reduce pollution load to the lake.

C1.1 Harnessing water quality from local to larger areas;

C1.2 Policies of water cost and pollution release cost;

C1.3 Research funds for clear industry production and pollution control.

C2. Construction of suitable PEEN in different region in TLB; namely:

C2.1 Recovery of macrophytes where they were there;

C2.2 "Jellyfish Engineering" (JE) for concentration and enrichment of algae by wind energy in strong wave regions (Pu, P., *et al.*, 1995-1);

C2.3 PEEN in mouth area of inlets with main pollution loading.

D) To develop foodstuffs for man and for livestock and non-food products resulting from pollution removal and eutrophication control aqua-plants and other aqua-products.

Take off algae and some parts of aqua-products from water body is essential for purifying water and to get economic benefits. Some of them have high concentration of heavy metals or other toxic elements. These aqua-products could not be used for foodstuffs. Others may be used for food production. Therefore, the following subjects are proposed:

D1. Foodstuffs for man and livestock from no-toxic biomass;

D1-2.1 Technology for concentration and enrichment of algae;

D1-2.2 Processing technologies for different aqua-products;

D1-2.3 Technologies for culture new species for foodstuffs.

D2. Non-food products from toxic aqua-products.

The main research topics for new strategy may be summarised in Fig. 3.

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