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Analysis of eutrophication state and trend for lakes in China

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ABSRACT

The article analyzes the present state and trend of eutrophication of lakes in China and concludes that lakes throughout the country are commonly undergoing the process of eutrophication: most of urban lakes are facing hypertrophication, many medium-sized lakes are of eutrophic state, some lakes even approaching to hypertrophic level. The five large freshwater lakes are in the condition of eutrophication, especially Lake Caohu and Lake Taihu are already in the state of eutrophication, water quality is deteriorating and ecosystem is destroyed. According to domestic and foreign experiences of the successful demonstrations in eutrophication and pollution treatment, this article puts forward the theory of combining source control with ecological restoration, which as the guidance for eutrophication control of lakes in China.

Key words: lake, eutrophication, countermeasure

1. GENERAL SITUATION OF LAKES IN CHINA AND ITS MAIN ENVIRONMENTAL PROBLEMS

China is a country boasting of many lakes, with over 24,880 lakes, 2300 of them with a surface higher than 1 km^2. The total area of all the lakes reaches 70,988 km^2, accounting for about 0.8% of the total area of the country, and most of lakes distributes in the East Plain, Qingzang Altiplano, Mengxin Altiplano, Yungui Altiplano, and Northeast Plain-hills, also called Five Big Lakes Zone. All lakes are with a total storage capacity of 707.7 billion m^3, of which freshwater storage capacity amounts to 225 billion m^3. Besides, there are 86,825 reservoirs, with a total storage capacity of 413 billion m^3. The two add to a total freshwater capacity of 6380×10^8 m^3, forming one of the most important freshwater resources in the country, playing a major role in supplying drinking water for the people as well as water for industrial and agricultural production, and aquaculture, travel industry, improving climate, generating electricity etc.

Owing to various natural geography and climate condition of Chinese lakes, in the recent several decade years discharge of large quantities of pollutants and human activities of irrational exploitation, environmental problems of lakes shows complexity and diversity. There are five main environmental problems: eutrophication, pollution of organic pollutants, salting of lakes in the west of China, shrinking of area and reduction of water quantity of lakes and destruction of ecosystem. But at present eutrophication is the most important environmental problem in many lakes and thus brings a tremendous influence on sustainable development of society and economy in lake regions.

2. PRESENT STATE OF TREND EUTROPHICATION OF LAKES

Investigation of 1980s and 1990s shows eutrophic lakes was mainly located in the middle and lower stream of Changjiang River, Yungui Altiplano, part of Northeast Plain-hills and Mengxin Altiplano. But all the urban lakes almost have been in the eutrophic level because the urban lakes are small and seriously destroyed by the domestic wastewater.

Owing to the fact that people have not realized the frailty of the lake ecosystem and lack of environmental awareness, human activities such as land reclaimation and destruction of plants around lakes, discharge of large quantities of industrial and agricultural waste water into lakes, and irrational development and utilization of natural resources of lakes, and so on have greatly affected the environment of lakes, which now face many environmental problems. And lakes throughout the country are commonly undergoing the process of eutrophication. As a result, the cycling of the ecosystem of many lakes is damaged, causing great losses to production and people's life in lake regions. Figure 1 shows trophic state of over 50 Chinese lakes. Eutrophic and hypertrophic lakes account for 66% and hypertrophic lakes amounts to 22%. Therefore, lake eutrophication has become an important environmental problem now.

Investigation shows that many freshwater lakes, even some lakes in the district where people seldom lived have accounted to the eutrophic state and most of them have been in the high trophic level. The characteristics of trophic state of lakes follow as:

1) The five largest freshwater lakes have been in the eutrophic level, they have been generally facing eutrophication with high nutrients (Tabs 1a, 1b), for

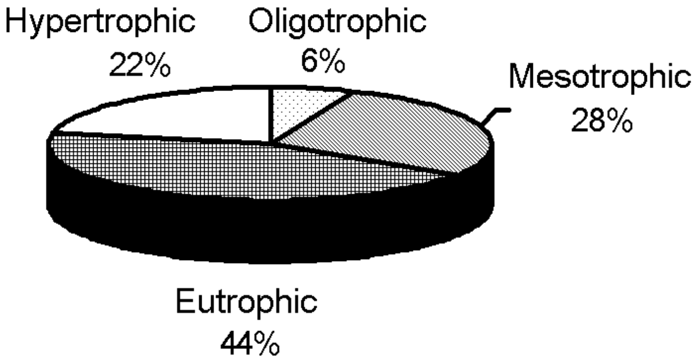

Fig. 1. Trophic state of main lakes in China.

Tab. 1a. Trophic state and estimation of over 50 Lakes in China. **Biggest freshwater lakes.

	Index (C_i)										TSI_G	Trophic conditions	
	Chl-*a* μg l^{-1}	TP mg l^{-1}	TN mg l^{-1}	SD	COD_{Mn} mg l^{-1}	BOD_5 mg l^{-1}	DO mg l^{-1}	Py	NH_3-N mg l^{-1}	pH		Estimated	Practical
East Plain Lakes Zone													
**Poyang L.	1.34	0.094	0.67	0.65	2.05	2.39	8.43	47.60			39.31	Meso-eutrophic	Meso-trophic
**Dongting L.	1.68	0.119	1.168	0.39	2.13	0.78	9.71				39.14	Meso-eutrophic	Meso-trophic
**Taihu L.	5.35	0.052	1.11	0.70	3.16	1.69	9.00				41.57	Meso-eutrophic	Meso-eutrophic
**Hongze L.		0.130	1.39	0.38	2.85		7.11				46.00	Meso-eutrophic	Meso-eutrophic
**Caohu L.	15.01	0.088	1.43	0.25	3.76	2.33					46.06	Eutrophic	Eutrophic
Qiandao L.	3.72	0.057	0.40	5.83	1.85	0.81					35.6	Meso-trophic	Meso-trophic
Gucheng L.	4.05	0.055	1.73	0.34	2.65	1.03	7.27				42.93	Meso-eutrophic	Meso-eutrophic
Nansi L.	3.73	0.21	3.38	0.50	21.38		6.79				51.40	Eutrophic	Europhic
Dianshan L.	5.98	0.088	1.95	0.57	4.30	1.73	8.90	50			43.26	Meso-eutrophic	Meso-eutrophic
Baiyangdian L. (80s)		0.082	2.30		5.00	4.24	11.68		0.396		47.79	Eutrophic	Eutrophic
Yangui Altiplano Lake Zone													
Dianchi Lake													
Caohai L.	77.41	0.504		0.40	14.74						61.84	Hypertrophic	Hypertrophic
Inner L.	101.74	1.401		0.28	16.58						67.00	Hypertrophic	Hypertrophic
Average of Dianchi L.	49.70	0.270		0.60	8.40						56.43	Hypertrophic	Hypertrophic
Average (except for InnerL. and Caohai L.)	16.76	0.123		0.65	7.07						50.26	Eutrophic	Eutrophic
Erhai L.(1995)		0.03	0.29	3.00		0.57		127			34.52	Meso-trophic	Meso-trophic
Cibi L. in Dali (1995)		0.02	0.29	1.40		0.53		135			35.07	Meso-trophic	Meso-trophic
Xihu L. in Dali (1995)		0.02	0.46	1.00		1.51		148			38.88	Meso-eutrophic	Meso-trophic
Haixihai L. in Dali (1995)		0.01	0.56	1.20		0.90		218			37.31	Meso-trophic	Meso-trophic
Tianchi L. in Dali (1992)		0.02	0.51	2.30		1.55		133			37.30	Meso-trophic	Meso-trophic
Jianhu L. in Dali (1993)		0.03	0.33	1.20		1.37		72			37.56	Meso-trophic	Meso-trophic
Mutunhai L. in Dali (1994)		0.02	0.28	0.8		0.86		254			37.90	Meso-trophic	Meso-trophic
Dayindian L. in Dali (1995)		0.02	0.49	1.70		1.50		611			39.54	Meso-eutrophic	Meso-eutrophic
Xinyun L. (1990)		0.045	0.67	1.50	3.98	2.16		418.3			41.96	Meso-eutrophic	Meso-eutrophic
Yilong L. (1988)		0.122		0.62	22.18	7.18	5.22		1.23	8.93	55.39	Hypertrophic	Hypertrophic
The east of Yilong L.		0.08		0.70	18.92	9.24	6.25		1.06	8.91	54.09	Hypertrophic	Hypertrophic
The middle of Yilong L.		0.154		0.65	20.51	6.59	6.18		1.34	8.95	55.32	Hypertrophic	Hypertrophic
The west of Yilong L.		0.133		0.50	27.31	11.15	3.24		1.30	8.92	58.54	Hypertrophic	Hypertrophic
Qilu L.		0.09	2.187	0.40	8.29	3.55	7.30		0.59	8.98	52.09	Hypertrophic	Hypertrophic
Fuxian L.1988)		0.0098	0.15	7.10	0.80	0.57		18.02			25.98	Oligo-trophic	Oligo-trophic
Qionghai L. (1988)	0.649	0.137	1.21	2.13	1.488	0.50	6.70	14.44	0.003		32.12	Meso-trophic	Meso-trophic

example, concentration of TN is above 10 times higher. Now Lake Taihu and Lake Caohu are already in the eutrophic state, with some waters even approaching to hypereutrophic level. And the other three lakes may also enter into eutrophication in the condition of higher nutrient load.

2) The urban lakes are facing serious eutrophication. According the investigation of many years, the urban lakes have been facing serious eutrophication with extremely high concentration of TN, TP, Chl-*a* and low transparency (SD) in water bodies and mainly in the hypertrophic level accompanying the serious organic pollution with very high concentration of COD_{Mn} and BOD_5 in waters, exceeding the Grade V water(GB3838-88) (Tab. 1).

3) Most of medium-sized lakes are already of the eutrophic state. Lots of medium-sized lakes are already of the eutrophic state with TN and TP approaching or

Tab. 1b. Trophic state and estimation of over 50 Lakes in China.

	Index (C_i)										TSI_G	Trophic conditions	
	Chl-*a* μg l^{-1}	TP mg l^{-1}	TN mg l^{-1}	SD	COD_{Mn} mg l^{-1}	BOD_5 mg l^{-1}	DO mg l^{-1}	Py	NH_3-N mg l^{-1}	pH		Estimated	Practical
Quingzang Lake Zone													
Qinghai L.		0.02	0.08	8.00	1.41		5.63				29.27	Oligo-Meso-trophic	Meso-trophic
Namucuo L.	0.042	0.031	0.411	9.00							27.70	Oligo-Meso-trophic	Oligo-trophic
Mengxin Altiplano Lake Zone													
Boshiteng L.	5.22	0.018	0.92	1.74	6.02	1.20	7.30	36.3			38.00	Meso-trophic	Meso-trophic
Caiwobao L.	0.099	5.93	0.27	5.21	1.58	7.76	22.00	1.32			51.05	Eutrophic	Eutrophic
Wulungu L.	0.031	1.98	3.30	13.36	1.41	8.86	8.10	0.55			43.89	Meso-eutrophic	Meso-eutrophic
Hulun L.		0.140	1.88	0.47	13.36	1.41	9.19	230			46.41	Eutropjhic	Eutrophic
Wuliangsuhai L.	4.45	0.067	1.873	1.21	6.44	1.86	6.43	1218			44.70	Meso-eutrophic	Meso-eutrophic
Hasuhai L.	15.51	0.090	1.21	0.88	7.68	2.31	7.35	1387			46.89	Eutrophic	Eutrophic
Dihai L. (1989)	32.56	0.22	2.25	0.61	132.47	2.18	7.18	111.75	0.025		51.55	Eutrophic	Eutropic
North-East plain hills Lake Zone													
Songhua L.		0.024	0.543	0.85	5.28			292			41.87	Meso-eutrophic	Meso-eutrophic
Tianchi L. (in Jilin)					0.78	1.20	8.90		0.064	7.7	23.82	Oligo-trophic	Oligo-trophic
Xingkai L.		0.10	0.55	0.60	5.54	1.96	8.50	3.11			40.43	Meso-eutrophic	Meso-eutrophic
Jingpo L.	9.62	0.40	0.98	1.32	7.00	1.21	8.89		0.170		46.25	Eutrophic	Eutophic
Wudalianchi L. (90)		0.419	1.67	1.15	7.97		7.97	225.15			47.92	Eutophic	Eutophic
Urban Lakes													
Luhu L.	86.40	0.22	3.04	0.38	9.68	8.71	9.66				55.75	Hypertrophic	hypertrophic
Liuhua L.	239.53	0.530	6.38	0.20	23.36	16.51	11.44				63.80	Hypertrophic	hypertrophic
Dongshan L.	132.00	0.420	6.15	0.29	11.74	14.26	6.93				60.71	Hypertrophic	hypertrophic
Liwan L.	149.65	0.620	8.53	0.31	14.43	17.50	4.74				44.70	Hypertrophic	hypertrophic
Xihu L. (in Hangzhou)	64.80	0.17	3.06	0.53	7.18	4.84	10.15		0.76		54.43	Hypertrophic	hypertrophic
Cihu L.	11.20	0.090	2.20	0.67	3.94	3.68	7.20				46.87	Eutrophic	Eutophic
DongHu L. (in Wuhan)	15.5	0.125	2.50	0.80	12.56	3.50		1000			51.52	Eutrophic	Eutophic
Moshui L. (in Wuhan)	156.59	0.740	16.05	0.15	13.6	25.71	4.26				62.87	Hypertrophic	hypertrophic
Xuanwu L. (in Nanjing)	103.00	0.478	3.50	0.25	8.95	10.70	8.64	4767			58.53	Hypertrophic	hypertrophic
Gantang L. (in Jiujiang)	37.60	0.240	1.73	0.56	26.17	6.41	8.03				54.00	Hypertrophic	hypertrophic
Nanhu L. (in Changchun)	113.11	0.529	5.45	0.19	78.28	9.76	8.58				63.30	Hypertrophic	hypertrophic
Mogu L. (1988)	32.12	0.21	2.33	0.62			9.88	1193			52.09	Eutrophic	Eutophic
Dianchi L. (Caohai)	77.41	0.504		0.40	14.74						61.84	Hypertrophic	hypertrophic
Reservoirs													
Miyun R. (1990)	3.02	0.0175	0.115	2.15	2.41	1.68	7.98	58.18	0.063		33.02	Meso-trophic	Meso-trophic
Yuqiao R.	6.56	0.02	1.24	1.97	3.36	3.02	10.26	99500			46.49	Eutrophic	Eutrophic
Dahuofang R. (88-91)	5.433	0.06	1.09	2.10	4.20		7.40	267.65	0.153		41.37	Meso-eutrophic	Meso-eutrophic
Gaozhou R.	0.739	0.022	0.369	2.11	1.64						32.60	Mesotrophic	Mesotrophic

exceeding the eutrophication transition concentration and some waters even reaching hypertrophic level (Lake Dianchi and Lake Erhai).

The concentration of COD_{Mn}, BOD_5, TP and TN is high in eutrophic lakes. Secchi disk transparency is lower than 1.0 m, and in most of them even lower than 0.5 m. Water quality is more and more deteriorating and the lake ecosystems appear to be greatly damaged.

Also the problem of nutrient elements released from sediment is serious. For example, 29% area of Lake Taihu is coverd with 0.1 m or more of highly contaminated sediment. The total storage capacity amounts to 69.1 million m^3. Algal nutrients (especially phosphorus) are the most important elements released from sediments, together with the refloating of small organic granule. There are so much nutrient elements in sediments that Lake Tajihu can still maintain an high level of eutrophication, even if all the external loading is reduced to zero.

As a consequence of the extremely high trophic condition, ecosystem in many lakes is commonly damaged due to deterioration of water quality, lowering of transparency, and destruction of lakeshore vegetation and wetland. The change of biological community accompanying the raising of pollutants and nutrients level is hereafter briefly summarized.

Phytoplankton densities largely increase, diversity of phytoplankton community declines, and dominant species of phytoplankton community change into species characteristic of eutrophic environments as cyanobacteria, which dominate in almost all the lake.

In eutrophic lakes phytoplankton produce high blooms and seasonal changes are reduced. In the hypertrophic and eutrophic lakes average yearly densities of phytoplanktonic algae vary between 1,000,000 and 10,000,000 ind l^{-1} and in the urban lakes the average algae per year amounts to between 10,000,000 and 100,000,000 ind l^{-1} (Tab. 2).

Diversity of phytoplankton community decrease. In eutrophic lakes seasonal change of composition of phytoplankton community tends to simplicity and the general tendency is that the higher is the concentration of nutrients in lakes simpler is the species composition

Tab. 2. Yearly average concentration of Chl-*a*, number of individuals and biomass of phytoplankton for some lakes in China.

		Chl-*a* (μg l^{-1})	n. ind. ($\times 10^4$ l^{-1})	Biomass (mg l^{-1})	Trophic state
Urban lakes	Luhu L. (Guangzhou)	86.40	9695.7		Hypertrophic
	Liuhua L. (Guangzhou)	239.53	1561.0	51.94	Hypertrophic
	Dongshan L. (Guangzhou)	132.00	4505.1		Hypertrophic
	Liwan L. (Guangzhou)	150.00	5664.0		Hypertrophic
	Xihu L. (Hangzhou)	64.80	4319.8		Hypertrophic
	Moshui L. (Wuhan)	157.00	9692.7		Hypertrophic
	Donghu L. (Wuhan)	15.50	322.4		Eutrophic
	Xuanwu L. (Nanjing)	103.00	4767.0		Hypertrophic
	Gantang L. (Jiujiang)	37.60	5316.3		Hypertrophic
	Nanhu L. (Changchun)	113.11	1237.4		Hypertrophic
	Caohai in Dianchi L.	139.00	6467.0		Hypertrophic
	Outer of Dianchi L.	23.80	1364.9		Eutrophic
Poyang L. (Jiangxi)		1.34	65.45		Meso-trophic
Taihu L. (Jiangsu)		5.35	32.1	5.86	Meso-eutrophic
Caohu L. (Anhui)		15.01	214.1		Eutrophic
Erhai L. (Yunnan)			562.3	4.66	Meso-trophic
Qilu L. (Yunnan)			290.9		Hypertrophic
Bositeng L. (Xinjiang)		5.22	340.9	1.36	Mesotrophic
Wulungu L. (Xinjiang)		0.031	630.3	1.34	Meso-eutrophic
Xika L. (Heilongjiang)				3.67	Meso-eutrophic
Jingpo L.(Heilongjang)		9.62	376.1	9.80	Eutrophic
Wudalianchi L. (Heilongjiang)			211.7	6.17	Eutrophic
Gucheng L. (Jiangshu)		4.05	162.9		Meso-eutrophic
Nansi L. (Shandong)		3.83	232.4		Eutrophic
Dianshan L. (Shanghai)		7.05	55.2		Meso-eutrophic
Fulun L. (Neimeng)			3430.5	8.10	Eutrophic
Wuliangsuhai L. (Neimeng)		4.45	1218.0	2.69	Meso-eutrophic
Daihai L. (Neimeng)		32.56	1127.3	1.19	Meso-eutrophic
Qionghai (Sichuan)		0.70	12.4		Mesotrophic

Tab. 3. Seasonal succession of dominant species of phytoplankton in some of eutrophic lakes in China. Legend: Ana = *Anabaena*; Ank = *Ankistrodesmus*; Aph = *Aphanocapsa*; Apha = *Aphanizomenon*; Ast = *Asterionella*; Bin = *Binuclearia*; Chla = *Chlamydomonas*; Chlo = *Chlorella*; Cho = *Chodatella*; Chrc = *Chrcoococcus*; Chrm = *Chromulina*; Chro = *Chroomonas*; Clo = *Closterium*; Coe = *Coelastrum*; Cos = *Cosmarium*; Cru = *Crucigenia*; Cry = *Cryptomonas*; Cyc = *Cyclotella*; Dac = *Dactylococcopsis*; Din = *Dinobryon*; Epi = *Epithemia*; Eug = *Euglena*; Fra = *Fragilaria*; Lyn = *Lyngbya*; Mel = *Melosira*; Mer = *Merismopedia*; Mic = *Microcystis*; Nav = *Navicula*; Ooc = *Oocystis*; Osc = *Oscillatoria*; Ped = *Pediastrum*; Pho = *Phormidium*; Pla *Planktosphaeria*; Rap = *Raphidiopsis*; Sce = *Scenedesmus*; Sch = *Schroederia*; Syn = *Synedra*; Tra = *Trachelomonas*; Eud = *Eudorina*; Anop = *Anabaenopsis*; Chl = *Chloroccum*; Nos = *Nostoc*.

Lake	Spring	Summer	Autumn	Winter	Trophic state
Cihu L.	Nav,Frg,Cyc,Sce,Ped	Sch,Chro,Osc,Mer,Dac	Osc,Mer,Ooc,Ped,Chla	Cry,Nav	Eutrophic
Gantang L.	Mer,Dac	Mer,Dac	Mer,Dac	Mer,Dac	Hypertrophic
Moshui L.	Sce,Mer,Cyc	Mic,Sce,Mer	Mic,Cys	Cyc,Mer,Chlo	Hypertrophic
Xihu L.	Osc,Syn,Apha	Lym,Sce	Lyn,Ose	Osc	Eutrophic
Nanhu L.	Mic,Mer	Mic	Mic		Hypertrophic
Luhu L.	Osc,Chro	Osc,Dac	Rap,Osc	Rap,Osc	Hypertrophic
Liuhua L.	Mic	Mic	Mic,Osc	Mic,Osc	Hypertrophic
Liwan L.	Cyc,Sce	Sce,Cyc	Sce,Eug	Sce,Cyc,Cry	Hypertrophic
Dongshan L.	Cyc,Cry	Cyc	Cyc,Chro	Cos,Osc	Hypertrophic
Honghu L.	Chlo,Eug,Ank,Eud	Chlo,Chro,Eug,Chl	Cos,Osc	Chl	Eutrophic
Caohu L.	Chro,Mic,Cry	Mic,Ana	Mic,Chro	Cyc,Mic,Chro	Eutrophic
Hulun L.		Mic,Ana,Chrc,Apha,Mer,Coe	Mic	Mic	Eutrophic
Wuliangsuhai L.	Chla,Sce,Mer,Chlo	Mer,Chrc,Mic,Coe,Ana	Mic,Sym,Ana,Lym,Coe,Sce	Sce,Mic	Eutrophic
Dianchi L.	Osc,Mic,Cyc,Syn	Osc,Chrc,Cyc,Cry,Sce,Eug	Cyc,Cry,Chla,Mica,Apha	Osc,Mic,Apha,Mica,Eug	Eutrophic
Mogu L.	Osc	Osc,Dac	Osc	Osc	Hypertrophic

of phytoplankton community and lower bio-diversity. In some lakes such as Gantang Lake composition of phytoplankton community is very simple and only one of algae species takes absolute advantage all over the year. In some lakes such as Luhu Lake, Liuhua Lake and Xuanwu Lake etc. only one of algae take advantage in most seasons (Tab. 4).

Dominant species change to the species indicating the eutrophication. Table 4 shows that in eutrophic lakes the dominant species are species characteristic of the eutrophic waters. In many lakes the quantities of the dominant species increase sharply, which leads to "waters bloom" (Tab. 3).

Tab. 4. Composition and succession of aquatic plants community in Caohai of Lake Dianchi. Y = yes; numerical value in the bracket means percent which this community accounts for all the area of all the aquatic plants.

Community type	1950s	1960s	1970s	1980s	1990s
Emerged macrophytes community					
Phragmites communis	Y(1.1)	Y(1.2)	Y(0.2)	Y	Y
Zizania caduciflora	Y(1.1)	Y(1.1)	Y(0.3)	Y	Y
Shoenoplectus tabernaemontani	Y(1.7)	Y(1.2)	Y(0.1)		
Acorus calamus	Y(1.1)	Y(0.1)	Y(0.01)		
Echinochloa crusgallia	Y(1.1)	Y(0.6)	Y(0.01)		
Hydrophyta natantia community					
Lemna minor	Y(1.1)	Y(0.4)	Y(0.004)	Y(0.001)	
A. imbricata			Y(0.2)	Y(0.001)	Y(0.01)
Eichhornia crassipes			Y(1.2)	Y(18.6)	Y(57.6)
Nymphaeoides peltatum	Y(4.3)	1	Y(0.02)		
Submerged macrophytes community					
Ottelia acuminata	Y(40.4)	Y(46.9)			
Vallisneria spiralis	Y(14.2)	Y(19.4)	Y(6.9)		
Chara vulgaris	Y(17.1)	Y(16.2)			
Ceratophyllum demersum	Y(2.8)	Y(2.5)	Y(0.02)		
Myriophyllum spicatum	Y(9.1)	Y(14.1)	Y(2.1)	Y(1.4)	Y(14.1)
Potamogeton malainus		Y(7.1)	Y(3.4)		
Potamogeton maackianus	Y(3.4)	Y(4.8)	Y(3.5)		
Potamogeton pectinatus			Y(10.4)	Y(10.1)	Y(15.3)
Potamogeton cripus	Y(1.1)	Y(2.5)	Y(1.39)	Y(0.01)	
Total communities	Y(14)	Y(15)	Y(16)	Y(6)	Y(4)

Tab. 5. Main composition and change of submerged macrophytes community in various trophic state in Dianchi and Erhai lakes.

	n. species	Dominant species	Trophic state
Dianchi Lake			
1950s	44	*O. acuminata, C. vulgaris, V. spiralis, M. spicatum, P. maackianus, D. demersum, P. cripus*	Oligotrophic
1960s		*O. acuminata, V. spiralis, C. vulgaris, M. spicatum, P. malainus, P. maackianus, D. demersum, P. cripus*	Oligotrophic
1970s	30	*P. pectinatus, V. spiralis, P. maackianus, P. malainus, M. spicatum, P.cripus, C. demersum*	Mesotrophic
1980s	20	*P. pectinatus, M. spicatum, P. cripus*	Eutrophic
1990s	12	*P. pectinatus, M. spicatum*	Hypertrophic
Erhai Lake			
1950s		*P. pectinatus, N. marina, O. acuminata*	Oligotrophic
1960s			Oligotrophic
1970s	18	*H. verticillata, C. demersum, P. maackianus, P. lucens*	Oligo-mesotrophic
1980s	15	*H. verticillata, V. spiralis, P. maackianus, C. demersum*	Mesotrophic
1990s	13	*P. maackianus, V. spiralis, Z. palustris, H. verticillata, C. demersum*	Mesotrophic

Accompanying the evolution toward hypertrophic status of lakes, the area of macrophyte gradually shrink. For example, before 1970s Lake Dianchi showed a good water quality with 100% coverage of aquatic vascular bundle plants, and in outer of Lake Dianchi with SD of over 2 m and 90% coverage of various aquatic vascular bundle plants. But after the middle of 1970s, due to gradual intensity of human activities, Lake Dianchi changes to eutrophication and water quality rapidly deteriorated, leading some species to die out, community composition became more simple. In 1990s the area covered by aquatic plants accounted for only 1.8% of the total lake area.

In 1950s Lake Dianchi have multiple community types: *Chara vulgaris* community, *Ottelia acuminata* community, *Vallisneria spiralis* community, *Myriophyllum spicatum* community, *Potamogeton malainus* community, *Acorus calamus* community, *Scirpus validus* community, *E. crusgallia* community, *Phragmites communis* community, and *Potamogeton crispus* + *M. spicatum* + *Hydrilla verticillata* + *C. demersum* community etc. After 1970s *Ottelia acuminata* community died out, in succession *C. vulgaris* community died out, owing to inning and repairing of lake shore *A. calamus* and *S. tabernaemontani* community deracinated too, *V. spiralis* community, *P. malainus* community and *P. cripus* + *M. spicatum* community were died gradually, *P. pectinatus* community with high tolerance for pollution evolved, and *E. crassipes* community took advantage. In 1990s in Caohai of Lake Dianchi *P. pectinatus* community of submerged macrophytes distributed in one or two sites; As for hydrophyta natantia, *E. crassipes* community took advantage with big biomass, and *Alternanthera sessilis*, *Oenanthe japonica*, *A. imbricate* and *L. minor* etc. distributed sporadically in *E. crassipes* community (Tab. 5).

During the oligotrophic state, there were 44 species of submerged macrophytes in Lake Dianchi and 18 spe-

Tab. 6. Trophic state and estimation of 34 lakes in China (1978-1980).

	Oligotrophic	Mesotrophic	Eutrophic
Number	4	16	14
%	11.76	47.06	41.2
Area (km^2)	3354.6	95929	5220.6
%	3.2	91.8	5.0

Tab. 7. Trophic state and estimation of over 50 lakes in China (1987-1989).

	Oligotrophic	Mesotrophic	Eutrophic
Number	1	7	14
%	4.5	31.8	63.6
Area (km^2)	29.5	2493	3084.9
%	0.53	44.45	55.0

Tab. 8. Pollutant load ($t\ y^{-1}$) of some lakes in China.

	Present pollutant discharge			Maximum allowable load		
	TP	TN	COD_{Cr}	TP	TN	COD_{Cr}
Dianchi L.	1021	8981	41,672	356	5012	5754
Taihu L.	5168	72,017	224,032	587	2167	59,532
Caohu L.	2677	26,802	66,773	225	5400	36,036
Erhai L.	122	1154				
Yuqiao L.	228	4458		28	888	

cies in Lake Erhai. In the mesotrophic state the number of species declined to 30 species in Lake Dianchi and 13 species in Lake Erhai. Such species as *O. acuminata* and *C. vulgaris* disappeared. In the hypertrophic state the number of species of Lake Dianchi declined to only 12, sporadically distributed in a few areas of the lake shore and with small scale (Tab. 6).

Some species with strong tolerance for pollution rapidly increased in density and biomass, while other species gradually declined and, in general, the distribution area of aquatic plants becoming small. For example, *P. pectinatus* come into being only one dominant species community with absolutely preponderant biomass, distribution area and high frequency, leading to *P. pectinatus* covering all the lake.

Frequent emergency of "water blooms" in many urban lakes of China may do serious harm to the lake. First it may produce obstacle to water function of lakes, then it will have impacts on aquaculture and scenic tourism, and algae toxin will endanger the health of people in the lake basin. In early 1980s microcystin (one of the algae toxin) was separated from Lake Donghu in Wuhan. The microcystin was also detected in the drinking water on Tongan (Fujian province) where has high rates of liver cancer. The highest concentration of microcystin in Lake Taihu was 38.5 $\mu g\ l^{-1}$ in 2001.

The trend of the eutrophic lakes in China is quite rapid. Table 7 shows trophic state of 34 lakes in China. Most of lakes were of in middle- trophic state, account for 91.8%. Eutrophic lakes account for 5.0% (Tab. 6). In only ten years, oligo-trophic lakes change to be middle-trophic lakes. The percent decrease from 3.2 to 0.53. Middle-trophic lakes change to be eutrophic lakes, the percent increase from 5.0 to 55.01 (Tab. 7). In 1996, Eutrophic and hypertrophic lakes account for 85%. Therefore, lake eutrophication in China has become an important environmental problems at present.

Excessive discharge of pollutants into lake is one of the important causes of eutrophication of lakes in China. Table 8 shows that now the ratio between present pollutant discharge and the maximal allowable load of the lake are of 3 to 10 in many lakes, and the value is even higher in urban lakes, which lead to deterioration of water quality and eutropohication of lake waters gradually.

3. COUNTERMEASURE FOR LAKE EUTROPHICATION CONTROL

All kinds of irrational activities and excessive nutrient load into the lake are the main causes of lake eutrophication and ecological disorder. Therefore, we should stop all kinds of irrational activities first, then take effective measures to restore lake ecosystem gradually.

Taking into consideration the domestic and foreign experience, the strategy to control eutrophication is hereafter described.

1) To combine source control with ecological restoration

Pollution sources are obviously the most direct reason of lake eutrophication, so control pollution sources is regarded as the preliminarily step. But lake is a lived waterbody and we could not control eutrophication effectively with the single measure of source control. Lake eutrophication treatment requires to take not only source control measures but also ecological restoration measures. Ecological restoration mainly pay attention to rehabilitation of aquatic plant in the shallow waters, restoration of lakeshore in the water-land crisscross area, and replantation of terrestrial ecological zone in erosion area. Only by ecological restoration measures, lake ecosystem could be restored to normal cycle and eutrophication could be controlled basically.

2) To protect lake from the point of view of the whole catchment

Lake is only part of a ecosystem of the whole lake catchment. Therefore to maintain normal ecosystem requires to control and protect lake from the point of view of the whole catchment.

3) The synthetical treatment and management

Synthetical treatment and managementis proved to be more rapid and effective measure in prevention and treatment of lakes.

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