Analysis of Water Pollution and Ecosystem Health in the Chao Lake Basin, China

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Keywords: *Climate change, Environmental health, Government policy, River basin, Sustainability*

EXTENDED ABSTRACT

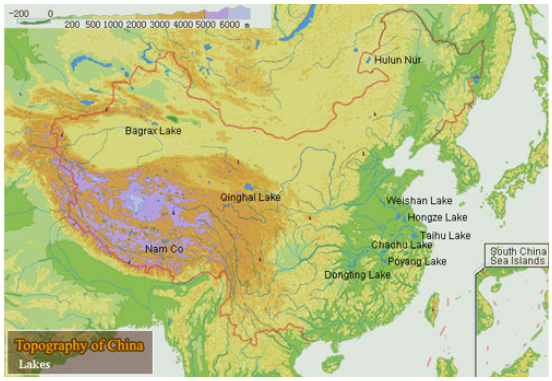
Water crisis is one of the greatest environmental challenges that China is currently facing. Since the 1970s lakes and rivers in China have been undergoing increasing water deterioration. By the 1990s some main water basins have been seriously polluted causing China's central government to initiate the so-called "three rivers and three lakes" (Liaohe, Huaihe and Haihe rivers, and Taihu, Chaohu and Dianchi lakes) project, which is aimed at alleviating or solving water pollution in these water basins.

Chao Lake (or Chaohu, see Map 1), one of the targeted water basins, is the most polluted lake in China. The article first analyzes the status quo of water pollution in the Chao Lake basin, including soil erosion, pollutants and nutrient concentration, pollution from fertilizers and chemicals, industrial pollution and the condition of the water body.

Following this, the authors develop an exploratory model to understand the basic reasons causing water deterioration, including natural and human-made factors. The elements of the model include natural features, population, residential activities, economic activities, culture and education and governance.

The paper argues that the restoration of the Chao Lake ecosystem needs a comprehensive policy and governance model at a regional and provincial level, which should also build on the implementation of a national sustainability strategy for China. This will allow China to achieve the goals of its recently adopted National Climate Change Programme.

Map 1. Chao Lake, China



Source: http://www.china.org.cn/english/en-shuzi2004/zr/dltz-hb.htm

1. INTRODUCTION

China is facing one of its greatest environmental challenges – a water crisis. Since the 1970s lakes and rivers in this country have been undergoing increasing water deterioration. By the 1990s some main water basins have been seriously polluted causing the central government to initiate the so-called "three rivers and three lakes" project which is aimed at alleviating or solving water pollution of three rivers, namely Liaohe, Huaihe and Haihe, and three lakes, namely Taihu, Chaohu and Dianchi, in China.

Chao Lake (or Chaohu) has a history of more than 15 thousand years. It is located near the middle of Anhui Province of China (see Map 1), 15 km east of its capital, Hefei City. Chao Lake is the fifth largest freshwater lake in China, with a surface area of about 750 km^2, and is an important water resource. Chao Lake has an area of 776 km² and when waters are at 11 m height, its volume is 403 million m³ (HMG, 2006). The average lake depth varies between 2 m and 3 m. The area around Chao Lake is an agricultural region, with about 5 million people living in the surrounding cities and towns. The lake is the major source of drinking water and water for irrigation. It is also very important for the local fishery industry.

Due to the poor infrastructure and inadequate environmental education, untreated or partially treated wastewater discharges directly into rivers and lakes surrounding the Chao Lake basin, flowing into the precious water resources of Chao Lake, which are particularly a drinking water source for Hefei and Chao Lake cities. Chao Lake is one of the three lakes in China assigned top priority for pollution control and monitoring. The Lake has been the primary source of raw water for Hefei for a long time, but over the years it has become extensively polluted and thus it has been largely abandoned (HMG, 2006). The Chao Lake region has a reasonable basis for economic development. It is one of the important production sources for agriculture and grain in particular. It has well-developed industry and transportation, including in Hefei and Chao Lake cities. However, the environmentally unchecked Chao Lake region's strong economic development has been causing serious water pollution.

Chao Lake is one of the most polluted river basins in China and it requires urgent attention. The remainder of the paper first analyzes the status quo of water pollution in the Chao Lake basin. Then an exploratory model is developed to understand the basic reasons causing water deterioration, including natural, economic and social factors. The paper concludes with some policy recommendations for improving the conditions of Chao Lake.

2. STATUS QUO OF CHAO LAKE BASIN'S ECOLOGICAL SYSTEMS

China faces greater environmental challenges than other major countries (Liu and Diamond, 2005). Its environmental problems include pollution, biodiversity losses, arable land losses, depleted fisheries, desertification, disappearing natural habitats, increasing frequency and scale of human-induced natural disasters, invasive species, overgrazing, interrupted river flows and water shortages. These issues are causing serious economic losses, social conflicts and health costs. Historically there has been, among others, severe water, air, soil, river, transport and industrial pollution. However water pollution, which started with the country's industrial development in the 1950s (Jusi, 1989), currently has the largest impact on people's normal life and needs to be solved urgently.

Chao Lake region's water system is very complicated, densely populated and surrounded by 35 lakes and rivers which criss-cross the urban environments of Hefei, Fei Dong, Fei Xi and Chao Lake City. Most of the rivers, such as Nan Fei River, Pai River and Feng Le River (see Table 1), are located in the western and northern parts of the Chao Lake's mountain areas with the southern part of the region having smaller flowing capacity. The rivers in the mountainous and hilly areas have distinctive characteristics which differ from the easily flowing valley rivers and consequently the Lake's region. All small or big rivers within the Chao Lake region play an important role in maintaining the region's ecosystem.

The most vital problem in the Chao Lake basin is eutrophication (Shang and Shang, 2005; Deng *et al.*, 2005). The nearby cities and towns have grown greatly in recent years, and their industrial wastewater and household sewage are discharged into the lake. Booming agriculture also pollutes its waters. Chao Lake has high nutrient concentrations from chemical fertilizer discharge, and consequently there are frequent algae outbursts. These algae hits reduce the available oxygen, killing fish and other organisms in Chao Lake. Efforts of cleaning up Chao Lake have included closure of some of the worst factories that caused pollution, improvement of municipal sewage treatment, reduction in the use of phosphorous containing detergents, some changes to farming practices, and adding algae eating fish.

2.1 Soil Erosion

Soil erosion in the Chao Lake region has been an important factor with a negative impact on this region's ecological environment. The situation of erosion in different areas is not the same (see Figure 2). More than 50% of Chao Lake's region suffers from soil erosion. During recent decades, the situation of soil erosion is getting worse due to the low forest coverage and fast population growth. The significantly affected by erosion areas reached around 1773 km², covering 17% of the region.

Table 1. Rivers in Chao Lake region

River Names	Areas km²	Area %	Rainfall mm
Nan Fei	1668	18	970
Shi Wu Li	114	1.2	970
Pai He	649	7	980
Hang Bu (with Feng Le)	4089	44.2	1220
Bai Shi Shan	840	9.1	1080
Tuo Ao	541	5.9	980
Lake areas	783	8.5	1030
Other	560	6.1	1000
Total	9244	100	

Source: Water Pollution Total Prevention Strategy in Chao Lake Region, 2001 – 2015

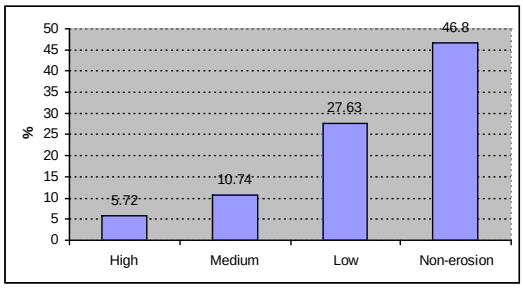


Figure 1. Soil Erosion in Chao Lake Region, 1995

Source: Water Pollution Prevention Plan for Chao Lake, 1995 and 2010 Projection

2.2 Pollutants and Nutrient Concentration

Water pollution and high nutrient concentration in Chao Lake are the most important characteristics of its ecological change and they have caused the most damage to the region's ecosystem. Population growth, economic development, increasing urbanization, industrialization and improper water management have added a lot of pressure to the region's ecological environment. As a result, industrial and agricultural discharges have increased the pollution level of Chao Lake's waters. By 1999, the pollution in the whole region was still very serious, particularly water pollution (Table 2). Hefei city is obviously the major source of Chao Lake's pollution.

2.3 Fertilizers and Chemicals

The use of fertilizers and chemicals causes agricultural surface pollution and water deterioration in the Chao Lake region where 75% of the population is rural. The main agricultural goods are wheat, vegetables, cotton and beans and farmers continually use chemicals and intensive agricultural methods in order to improve yields.

Table 2. Chao Lake Region's major pollutants, 1999

Source: Water Pollution Total Prevention Strategy in Chao Lake Region, 2001 – 2015

Regions	**Wastewater**	**Wastewater Discharge** 10 000 t/year	**TP** t/year	**TN** tone/year	**CODcr** tone/year
	Industry	11198	159.76	2644.99	23710.14
Hefei	Living	10892	600.32	8854.49	21986.18
	Surface	4248	409.12	4999.72	1639.46
	uncontrolled		36.2	1071.8	
	Total	26272	1205.4	17571	47335.8
		2191			
Chao Lake	Industry		65.01	476	6826.46
	Living	4745	246.12	1568	14235.4
	Surface	1518	271.27	1704	1688.57
	uncontrolled		18.6	252	
	Total	8454	601	4000	22750.4
		820			
Liu An	Industry		27.5	141	1794.41
	Living	565	122.3	733.54	2296.42
	Surface	652	187.95	1141.07	709.2
	uncontrolled		12.25	149.39	
	Total	2037	350	2165	4800
		14209			
Chao Lake	Industry		252.27	3261.99	32331.41
Region	Living	16139	968.74	11156.03	38517.6
	Surface		868.34	7844.79	4037.23
	uncontrolled		67	1473.2	
Total		36766	2156.4	23736	74886.2

Notes: CODcr–chemical oxygen demand removal capacity; TN–total nitrogen, TP–total phosphorus

2.4 Industrial Pollution

Since the foundation of the People's Republic of China in 1949, particularly after the economic reform and open door policy, the Chao Lake region developed fast in industry, transportation and service sectors. In particular, in Hefei and Chao Lake cities, light industry and industries of steel, mechanics, building materials, chemicals and textiles are important industrial systems. Industrial pollution is shown in Table 3.

2.5 Water Body Pollution

The most obvious ecological problem in the Chao Lake region is its water pollution and high nutrient concentration. These problems have developed over a very long time. In the 1960s, the Lake's water nutrients were similar to the other major fresh water rivers in the country. Statistical records in the Chao Lake Diary show that TN increased 21 times between 1963 and 1984 and pH value increased from 7.43 to 7.91. Since mid 1980s, the degree of high nutrient concentration in the Chao Lake flowing region increased further due to the surface pollution caused by the fast growing population and the fast development of industry and agriculture. According to the statistical record of the Chao Lake water quality monitoring survey all indicators deteriorated even further between 1986-1995. Data collected in 1999 show overall degree of deterioration at Grade IV for the whole lake (I being non-polluted), with many points at Grade V and VI. The situation in the west half of the lake is the most serious (Shang and Shang, 2007).

Table 3. Wastewater discharge from industry in Chao Lake Region, 1999 and 2002

	1999		2002	
Areas	Discharge 10,000 t	% above standard	Discharge 10,000 t	% above standard
Hefei	9197.9	64.3	7032.4	98.4
Liu An	3386.8	82.2	3867.1	98.3
Chao Lak	1891.8	82.6	3839.6	99.9
Total	14476.4	70.9	14739.1	98.8

Source: Anhui Statistical Yearbook, 2000-2003

In order to understand what is happening with the Lake there is a need for a thorough analysis of the pollution causing activities.

3. REASONS CAUSING WATER DETERIORATION IN CHAO LAKE BASIN'S ECOSYSTEM

The reasons causing ecologically environmental deterioration in the Chao Lake region include both natural and human-made factors. They are shown in the model in Figure 2. The top two factors, namely natural features and population are more difficult to control while the remaining four are entirely human-made. What the model shows is that there is a need for a sustainability policy in order to protect and restore the environmental health of Chao Lake.

3.1 Natural Features

The main reasons that caused Chao Lake' ecological deterioration are human-made, however some natural factors also need to be considered. From a geographic perspective, the shape of the area of the whole region is high in the west and low in the east. Most of the water from the water systems flows into the Chao Lake and as a result, it accepts most of the pollutants. In addition, heavy rainfall and concentration of the raining period cause soil erosion, including damaged plants, flood and sand falling and leading into the Lake's bed.

Despite this challenging natural environment, human activities have contributed even further to the poor ecological health of Chao Lake.

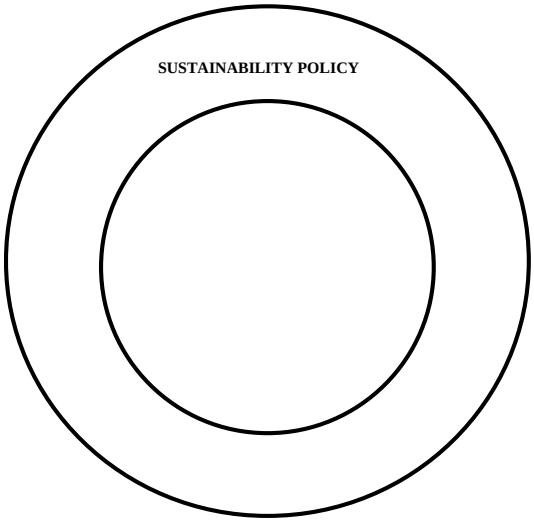


Figure 2. Ecological restoration model

3.2 Population

The increasing population in Chao Lake region (estimated at more than 10 million), particularly the fast growing, urbanization and industrialization in Hefei city (its population is estimated at 4.5 million in 2005), are major factors that cause total imbalance of this region's ecological system (HMG, 2006). In comparison with other regions, the population density in Chao Lake is very large. This population requires and consumes constantly increasing amounts of resources, including water and energy. It also generates waste that goes back into the ecosystem.

3.3 Residential Activities

The large population in the Chao Lake region produces a huge amount of everyday life wastes

and puts a lot of pressure on the regional environment. It was estimated that 200,000,000 tons of everyday wastewater is discharged into Chao Lake from households and industries and most of the wastewater goes into the lake without a proper treatment (Xu *et al*., 2005). Sewage systems in Hefei and Chao Lake cities need to be significantly improved in order to reduce the pressure on the water body. The distribution of the daily residential waste discharge for Hefei is presented in Figure 3.

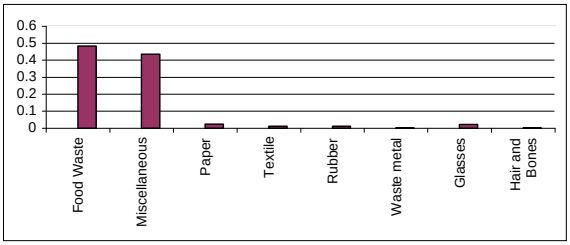


Figure 3. Residential waste distribution in Hefei
Source: Total Strategy of Ecological Construction and Policy Research Report in Chao Lake region

3.4 Economic Activities

Besides the population growth and the changing lifestyle of the residents, economic development and the style of agricultural production are also major contributors to the environmental deterioration. There are three economic factors to cause Chao Lake's regional pollution. The first is agricultural production and rural development; the second is industrial pollution, and the third is that there are some issues in the whole economic structure. The unbalanced economic development of the region is caused by the concentration of industries and services Hefei and Chao Lake cities while the other areas are heavily dependent on traditional agriculture. Both put huge pressure on the environment, be it in different ways.

3.5 Culture and Education

In comparison with the average education in China, the Chao Lake region's educational level is not much different, but the imbalance between urban and rural is very big which affects people's knowledge and environmental awareness. In general, there is not enough attention paid to environmental education (Kristen, 2005) while both governments and the private sector are pursuing economic development and economic benefits leaving environmental issues to the NGOs (Hong *et al*., 2006).

Chinese environmental laws and regulations in particular are largely piecemeal written, they lack effective implementation and there is no evaluation of long-term consequences (Liu and Diamond, 2005). There is a need for a systems approach in Chinese education that would build a culture that is more environmentally oriented.

3.6 Governance

Other related factors that affect environmental deterioration in the Chao Lake region are the regional management systems and their related policies. Since the foundation of the People's Republic of China, regional governments have paid a lot of attention to economic development. Unfortunately Chinese people have paid a high price due to their ignorance of environmental protection and unsustainable use of the limited resources. Therefore it is vital to resolve the following three conflicts: (1) conflict between population growth and the carrying capacity of the natural environment; (2) the region's rate of economic development and environmental protection; and (3) the death and life of the region's water body.

4. POLICY IMPLICATIONS

It is argued in this paper that the restoration of the Chao Lake ecosystem needs a comprehensive policy and governance model, which should also include the implementation of a national sustainability strategy. The Chao Lake region is part of the Anhui Province and there is also a need for a sustainability strategy for the province itself. Regarding the conflict between population and the environment, it is impossible to change population size in a short time, but the impact from it can be reduced through building a better ecological awareness, which will allow a better protection of the natural environment and improvement of the population's quality of life in an environmental sense. The conflict between economic and environmental priorities is a substantial one; it is essential to choose a proper model of economic development which allows the region's economic growth to continue. Firstly, it is important to adopt a better agricultural model around ecological agriculture as a basic strategy of developing the rural economy and improving the ecosystem. Secondly, clean technologies and production modes should be promoted, and there should be policies banning industrial pollution. Thirdly, the region should take advantage of Hefei as a technology hub, including the existing "Technology City", to develop a new service sector and bring the region to the age of information.

China's newly released National Climate Change Program (NDRC, 2007) is aiming at restructuring the country's economy, promoting technology advancement and improving energy efficiency (the government's goal is to improve the overall energy efficiency in 2010 by 20% over 2005's level). The measures include expanded research and use of fresh energy-saving technologies, improvement of agricultural infrastructure, water resource management and greater investment in public environmental education. There are many factors that have been causing the water pollution in the Chao Lake region. Using proper technologies or adopting better management measures are not enough to solve these problems. There is a need for a more concerted and all encompassing effort to restore the ecological health of the area.

In order to re-establish Chao Lake's ecosystem and its management system, it is important to remember that the Lake's particular ecosystem is formed by both biological and non-biological elements. This large flowing lake is linked to its surrounding major lakes and rivers. This system can be affected by all biological, chemical and physical factors and the complicated relationships between them. The wildlife and human beings within this region all depend on the effective and healthy running of the ecosystem in the Chao Lake region.

Since the 1980s, many measures have already been adopted, such as assessing Chao Lake's ecosystem, formulating strategies and ecological protection regulations and funding for research on the high nutrient concentration in the Chao Lake region. However these are far from sufficient to help achieve sustainability – balance in ecological protection, economic prosperity and social harmony in development. It is necessary to transcend the traditional thought of pollution control and management and thus to develop a complete model for environmental management within the context of achieving regional sustainability.

5. CONCLUSION

The Chao Lake basin faces the problems of increasing pressure on its ecosystem due to the large and growing regional population and environmental deterioration caused by continuing industrialization, urbanization and land degradation. The ecological burden from the growing population is going to further create more difficulties in dealing with the water related issues. Solving Chao Lake basin's problems of water deterioration will add more pressure on the region's economy.

In order to provide sustainable water resources for the residents in the region, the local governments, business, community and NGOs need to collaborate to make strategic policies and promote environmental education as well as improve the legal systems and regulations to monitor and manage Chao Lake's regional water resources. There is a need for proper strategies to be formulated in order to achieve the objectives and targets of the enhancement of Chao Lake basin's ecosystem health and its regenerative capacity.

This paper suggested that the restoration of the Chao Lake ecosystem needs a comprehensive policy and governance model. The changes in the Chao Lake region's ecosystem were caused by both natural and human-made factors. The sources of pollutants are mainly from human-made waste discharge, the region's economic development, particularly from its fast industrialization and urbanization. For example, Chao Lake's high nutrient contamination was mainly caused by the region's waste discharge, but Chao Lake's own natural life-cycle should also be in consideration.

In order to understand the real reasons of the ecological problems in the Chao Lake basin and solve them in an effective way, it is essential to recognize that the creation of those ecological problems was not only the Lake's own ecosystem, but also from the total developmental situation of the socio-economic characteristics within the region. The only solution to rebuild the unhealthy Chao Lake basin is to make sustainable development possible for the whole region and the province, which should build on the implementation of a national sustainability strategy for China.

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