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Analysis on Water Environment Capacity of the Poyang Lake

Yan Bangyou[1,a] ,Xing Jiusheng[2] ,Tan Huiru[3] ,Deng Shaoping[1] ,Tan Yinning[4]

[1.] *Office for Mountain-River-Lake Development and Management Committee, Jiangxi Province, Nanchang 330046,China,*
[2.] *Hydrologic Bureau of Jiangxi Province, Nanchang 330002, China*
[3.] *Jiangxi Academy of Sciences, Nanchang 330029, China,*
[4.] *Hainan University, Faculty of Management 570228, China*
[a] *a.sree@tom.com*

Abstract

A proper model was selected in this paper for analyzing the capacities of water environment of Poyang Lake for accommodating the several main pollutants quantitatively on the basis of the existing data. The results show that the maximum annual capacities of COD, TP and TN are 768288.5t, 7161.2t and 143224t respectively by taking the second-class national water standard as reference and they are 1576982.5t, 14322.4t and 286448t respectively by taking the third-class national water standard as reference. The paper further analyzed the system adjusting capacity of water environment of Poyang Lake with the following results: The flood adjusting amount for the five upper rivers of Poyang Lake at their maximum inflow reaches 74 to 246×108 m3. The flood-adjustment rate is about 16 to 60 percent with its annual average adjustment rate of 34%. The occurrence of serious flooding disaster of Poyang Lake is 16%. The carrying capacity of the flooding-proof system of the lake region is relatively low. About 29.9 to 53×108 m3 water in the dry season are needed for maintaining ecological functions of the lake. Water and soil erosion, and land desertification in the lake region are not under control currently. Annual ecological and environmental cost reaches 19.85×108 RMB occupying 10.56 percent of the total GDP of the Poyang Lake region. In a word, the economic, social and environmental development coordinating level of the Poyang Lake region is low.

Key Words: Poyang Lake; Water Environment; Carrying Capacity

Introduction

Carrying capacity of water environment is the capability of pollutants acceptance of a functional water environmental system (i.e., pollutants acceptance capability) and adjustment capacity to changing basic elements (i.e., adjustment capacity of a system) (Liang, et al, 2001). This paper aims to analyze carrying capacity of the Poyang Lake from two aspects: to analyze the maximum amount of pollutants acceptance of a water body under state quo condition, and second, to evaluate adjustment capacity of the Poyang Lake to changing basic elements of water environment.

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Pollutants acceptance capacity of the Poyang Lake

The situation. According to national standard, about 64.2 percent of the total Lake area fell into the second class, 30.5 percent to the third and about 5.3 percent was the fourth class that exceeds the standard. Regarding to source of pollutant, total phosphorus, total nitrogen, and permanganate index and volatile are on the top of the list. Amount of annual pollutants emission is 2517.9×10^4 t, among which COD content is 1602.6 t，total phosphorus is 12.9 t and total nitrogen is 168.6t. COD, total phosphorus (TP) and total nitrogen (TN) are thus the major pollutants.

Targets of water quality. The Poyang Lake provides water resources for agriculture, industry, fishing, domestic consumption, landscape and ecological environment of the surrounding areas. The water quality should meet the general requirement of the national standard or the so-called "Standards for Surface Water Environmental Quality" (GB3838-2002) and the water resource should fall into the third or below the third class, so that it can ensure coordinating development among social, economic and environmental dimensions of the regions around the Lake, and maintain ecological process and life support system of the wetland, and maintain the biodiversity and secure sustainable use of wetland ecological system and bio-species.

Marginal conditions

Table 1 Marginal Conditions for Calculating the Capacity of Water Environment to Accommodate the Organic Matter

Annual inflow（m^3/s）	Designed volum of the lake（$108m^3$）	Time for self-cleannes（s）	Integrated attenuation coefficient（1/s）	COD mn Status concentration（mg/L）	COD mn under Class Ⅱ（mg/L）	CODmnunder Class Ⅲ（mg/L）	CODcr /CODmn
4835	70.06	8.9×10^6	6.9×10^{-8}	2.1	4	6	2.4

Table 2 Marginal Conditions for Calculating the Capacity of Water Environment to Accommodate N and P

Annual inflow（10^8m^3）	Annual outflow（10^8m^3）	Average depth（m）	Lake Aarea（m^2）	TP under Class Ⅱ（mg/L）	TP under Class Ⅲ（mg/L）	TN under Class Ⅱ（mg/L）	TN under Class Ⅲ（mg/L）
1525	1525	2.53	27.69×10^8	0.025	0.05	0.5	1.0

Statistical models. The Poyang Lake is a shallow water lake with huge land coverage. And an equal amount between precipitation and evaporation, and inflow and outflow of water from the lake exists. But the water environment is heterogeneously mixed and easy to degrade, therefore, the following model is chosen for the calculation of water quality.

- COD capacity of water environment

$$W=86.4\ \frac{Cs-Co}{EXP^{(-kt)}}\ Q \qquad (1)$$

Where,

COD- maximum allowable loading，kg/d

Cs—COD control concentration，mg/L

C_O—COD status concentration，mg/L

K—COD integrated attenuation coefficient，1/s

t— time for self-cleanness，S

Q—inflow quantity，m^3/s。

- Capacity of water environment to accommodate N and P

The following formula is used for calculation of capacity of water environment to accommodate N and P:

$$W=Lp\cdot A \qquad (2)$$

$$Lp = \frac{Cs \cdot \delta \cdot h}{1 - Rp}$$

Where,

W - maximum allowable accommodation of N and P，g/a；

Lp - maximum allowable accommodation per unit of the Lake area，$g/m^2 \cdot a$

Cs - control concentration of N and P，mg/L

Rp - resort coefficient，$Rp=0.426e^{-0.271qes}+0.574e^{-0.00949qes}$，unit less

$qes=Q_i/V$

Where,

V - designed water quantity of the Lake，m^3

Q_i - annual inflow of water，m^3/year

H - average depth of water，m

$\delta=Qa/V$，1/a

where,

Qa - annual outflow of water，m^3/year

A - area of the Lake surface，m^2

Capacity of water environment and existing amounts of pollutant acceptance. As far as water quality standard for the class II is concerned, the maximum annual accommodation of COD、TP、and TN is 768288.5t，7161.2t，and 143224t respectively；while those figures are 1576982.5t，14322.4t，and 286448t when the water quality falls into the third class. Table 3 shows the comparison between the capacity of water environment and existing pollutant acceptance amounts.

Table 3 Capacity of Water Environment and Existing Pollutant Acceptance Amounts of Poyang Lake

		COD（t/a）	TP（t/a）	TN（t/a）
Status pollutants acceptance	Direct inflow	1602.6	12.9	168.6
	Indirect inflow		342.55	4904.71
	Inflow from the five rivers	632570.4	13599.02	92111.07
	Total	634173	13954.47	97184.38
Pollutant acceptance under class Ⅱ		768288.5	7161.2	143224
Pollutant acceptance under class III		1576982.5	14322.4	286448

Note: 1) direct inflow includes those from precipitation (TN2462t/year, TP74.38t/year), dust fall (TN36.8t/year, TP74.38t/year), emission from the mud (TN2249.91t/year, TP180.89t/year), and seasonal bird (TN156t/year, TP24t/year)。

2) Data source: Inspection center for Water Environment in Jiangxi Province.

Adjustment capacity of water environmental system in the Poyang Lake

The fundamental elements of water environment in the Poyang Lake are water body including water quantity, quality, inflow and outflow condition), lake basin including basin shape, area and volume, as well as lake bank covering lake bayou vegetation and landscape. Changes of any of the elements would probably cause the change of the function of water environmental and safety of ecological condition. Adjustment capacity of water environment to changing basic element(s) reflects ecological safety and development levels of water environment and the watershed.

Carrying capacity of floods and safety. Table 4 shows flood occurrence in Poyang Lake over the past decades. Degree of flood occurrence in the Poyang Lake is judged on the basis of water levels at Changdu Water Station. Sever flood years, with an average water level of ≥19.5m, was observed in 24 years from

1951 to 2000 (Table 4), and its occurrence is 48 percent, and the area of farmland affected seriously by the flood is 10,000 ha to 40,000 ha. During this period, eight most sever flood years, with an average water level of ≥20.5m are found, and its occurrence is 16 percent, above 40,000 ha of farmland was seriously damaged by the flood, in some areas, the damaged farmland exceeded 200,000ha. Beside, human's living and important transportation facilities have been destroyed.

Table 4 Changes and Occurrences of Flooding in Poyang Lake in the Past 50 Years (1951-2000)

YEAR		1951—1960	1961—1970	1971—1980	1981—1990	1991—2000
Sever floods	No. of years	1	4	6	5	8
	Frequency（%）	10	40	60	50	80
Most sever floods	No. of years	1	1	3	2	5
	Frequency（%）	10	10	30	20	50

Carrying capacity of floods is defined as the adjustment capacity of the wetland in the Lake to floods, i.e. capacity and function of the Lake. It can be calculated by using the figures of adjustment volume and rate (formula 3 and 4).

Adjustment volume: $\triangle W=W_{inflow}—W_{outflow}$ (3)

Adjustment rate: $d=(\triangle W/W_{inflow})\times 100\%$ (4)

Where, W_{inflow} and $W_{outflow}$ are volumes of water inflow and outflow at the same time period.

When the value of both adjustment volume and rate are positive, volume of water inflow is greater than outflow, and it is within the adjustment capacity of the Lake, otherwise, it is beyond the capacity to adjust. Following analysis of flood adjustment capacity is based on the survey data in 1954, 1955, 1962, 1969, 1973, 1983, 1996, and 1998.

When inflow from the five lakes is high and the water level at the bayou (i.e., the Changejiang River) is low, the adjustment capacity of the Poyang Lake to the maximum inflow caused by flood is 74～$246\times10^8m^3$, adjustment rate is 16 percent to 60 percent and the average adjustment rate is 34 percent.

While in case of a small amount of inflow from the five lakes, and a high water level (≥19 m) at the bayou of Changjiang River, the adjustment capacity is -241～$-23\times10^8m^3$ and the rate is -14%～-82% in 1954, 1955, 1962, and 1998；and those values are 6～$38\times10^8m^3$ and 3%～10% in 1969, 1973, 1983, and 1996. The most sever floods occurred in the Changjiang River and the Poyang Lake in 1954, 1983 and 1998 when water level at the bayou is above 21 m, and the adjustment capacity is $-126\times10^8m^3$, $23\times10^8m^3$, and $-69\times10^8m^3$ respectively, adjustment rate is -24%、13%、-13% respectively. The results imply that the adjustment capacity of the Poyang Lake to the floods is becoming weak, and even lose, with an increasing of the water level at the bayou of the Changjiang River, which could bring negative effects on the water level during flooding season down streams.

Safety of flood prevention system refers to dike system of the lake. The dike at the bayou of the Lake basin of the Poyang Lake is 22.5 m, and the dike at the five lakes could control sever flood occurring every 20 years. The dike system has so far reached the standard proposed. However, some dangers still exist, for instance, the 30 dike systems using for protection of 5 to 10 mu of farmland, and transportation systems at local levels could only prevent floods occurring every five years, not to say others small and middle scale dike systems along the lake. Therefore, carrying capacity and safety of the Poynag Lake is weak among the five largest fresh water lakes in China. Frequency of flood tends to be high among the others.

Ecological water demand. Ecological system of wetland in Poyang Lake is formulated on the basis of water environment. Owing to the big fluctuation of water levels (9.79 to 15.36m in the bayou), the water level increases in summer and decrease in winter, vegetation succession including types, species and their distribution normally occurs in the wetland, as well as growth status and amount of biomass, and therefore food chain composition, particularly for fish and bird. Degree of vegetation succession depends on the fluctuation of water level, lasting time of each of the water levels, and amount of mud accommodation as well.

Total vegetation area in the wetland of the Poyang Lake is $2262\times10^4 km^2$. It's distribution is irregular annularity starting from the bank to the center of the Lake, and changes with the environment and water depth. And is classified as the belts of hygrophyte, emergent aquatic plant, floating-leaved vegetation, and submerged macrophytes. Floating plants distributes between emergent aquatic plant and floating-leaved vegetation.

Natural succession of vegetation in the entire lake is dominated by the beach vegetation stretching, with an annual speed of 5-10 m towards downstream and replaces the hygrophyte. In some areas, for instance, along the river cannel between Kangshan and Tangying, the stretching speed is very high and the carex moved 15.5 m downstream in 61 years from 1927 to 1988, with an average annual speed of 270 m. Within the same period, the carex in the left bank of the main branch of the Gangjiang River moved, with an average annual speed of 140 m, 8.5 m downstream. While vegetation succession in seasonal lake or papilionaceous depression land during dry season tends to be like emergent aquatic plant-hygrophyte-submerged macrophytes moving toward the center. The final picture of such kind of movement would be gradual vanishing of hygrophyte with the disappearance of the lake, and therefore, the unavailability of habitat for aquatic animals like fish and birds.

The process of vegetation succession is actually a positive succession of lake-swamp-continent implying shrinking of wetland water environment and weakening of eco-system service. In order to maintain eco-balance of the wetland of the Poyang Lake, the low water level of the dominant lake should be between 13-14 m. However, current low water level is only 11-12 m, and therefore, 29.9×10^8 to $53\times10^8 m^3$ inflow is required during dry season, or reduced outflow during water dropping season should be the same as water required for the balance , and this is ecological water demand for the maintenance of eco-balance.

Soil erosion and land desertification. Changes of the surrounding areas and vegetations in Poyang Lake will affect significantly water environment and adjustment capacity, and hence cause soil erosion and land desertification, which is summarized as below:

Soil erosion: total area of soil erosion is 350,000 ha accounting for 17 percent of the total area of the lake. Total erosion area in the entire watershed is 352×10^4 ha accounting for 21.5 percent of the whole watershed.

Land desertification: based on Remote Sensing data, the total area of desertification in Poyang Lake is 38,900 ha accounting for 2.2 percent of the total Lake area and 30 percent of the total area of the province, among which 6,700 ha is fixed sand dune, 13,600 ha semi-fixed sand dune, and 8,500 ha traveling dune. Area of farmland converted from sand land is 10,000 ha.

There is an increasing trend in the area of desertification. According to a survey data, area of desertification increase from 18,620 ha in 1988 to 23,403 ha in 1995 with a total increase of 4783 ha. And airslake mobile sand expands 3 to 5 maters every year. .

Conclusion and Recommendations

The following conclusion is made based on the findings:

TP in the Lake exceeds the class II standard. TP annual and daily emission is 13954.47t and 38.23 t respectively that is extremely higher than the controlled annual emission of 7161.2t and daily emission of 19.62 t respectively. Therefore, emission should be limited, and annual emission should be controlled within 6793.27t and daily 18.61 t. COD pollution occupies 82.5 percent of the controlled pollutant emission, and TN 67.9 percent. According to the Class III standard, pollutants emission falls into allowable range.

Adjustment capacity of the Lake to the changing elements of water environment (water quantity and quality, and special patterns of the Lake) is weaking which can be observed from the following facts:

- Spatial patterns of the lake is changed due to cultivation and mud accumulation. Total volume of adjustment reduced by $60\times10^8 m^3$ that is 20 percent of the total volume of the Lake. Therefore, capacity of

the lake to adjust flood damage is decreasing, and also thanks to the unavailability of standard flood prevention system, floods occur frequently and safety is low.

- Beach vegetation moves downwards and replaces hydrophyte. Succession of beach vegetation tends to be in the same direction with that of mud accumulation, and available water during the dry season in the Lake could no longer maintain originally balanced eco-system. The wetland changes following the procedure of formulation-expansion-vanishing, which takes decades. Additional efforts and actions are needed to control this process in order to reduce basin sinking and control water level.

- Trend of the increase of pollutants acceptance capacity of the Lake with the degree of pollution is shrinking. Current water quality can only maintain the Class II and III.

- Weakening of carrying capacity and pollutants acceptance of the Poyang Lake causes unbalanced development between society, economy and environment. Result from green GDP shows total loss of eco-environment including soil and water erosion, desertification, mud accumulation, environmental pollution and schistosome in the Lake area is 19.85×10^8 RMB accounting for 10.56 percent of the total GDP of the Lake. It is thus the poorest area of the Lake.

Recommendations proposed for further action are as follows:

- Improve water quality and control the pollutants from the source like Gan River, Rao River, and Wu River, and to reduce pollutants emission from those sources. Moreover, water treatment plant is needed in the urban areas along the rivers and the lake. Last, green production techniques and products should be further supported, and use of chemicals should be limited.

- A lot of activities have been taken to protect the Lake area, for instance, reclamation in the Poyang Lake has been ceased since 20 years ago, and dike system also improved over the years, and the government has been implementing the policy of conversion of farmland into lake, and resettlement since 1998, the year of the most sever flood occurred in the area. And many people could be able to have substantial livelihood. However, many problems remain to be solved such as identification of suitable area, duration and volume of water for flood inflow.

- To enhance reduction of soil erosion and desertification. Eco-reconstruction and vegetation recover of both forest and sand vegetation need to be stressed. In particular, forest structure should be readjusted, and the proportion of commonweal forest, as well as broadleaf and pin-broad leaf forest should be increased. It is expected this adjustment can further improve forest health and prevent soil erosion, and therefore water quality of the Poyang Lake.

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References

[1] Liao Wengen, Peng Jing, He Shaoling. Study on Carrying Capacity of Water Environment and Its Evaluation System, Water Resources and Carrying Capacity of Water Environment. Department of International Cooperation, Sciences and Technology of Water Resources Ministry, China Hydraulic and Hydroelectric Press 2002

[2]Zhu Haihong、Zhang Ben，Poyanghu, China Science and Technology University Press, 1997, p:112-113、84-85、214-215

[3] LIU Xinzhong, YE Juxin, et al. Jiangxi Wetland. Beijing: Chinese Forestry Press, 2000. p: 208