

BIOLOGICAL RESTORATION OF URBAN RIVERS IN CHANGZHOU --NORTH RIVER  
AS CASE STUDY

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## **Certificate**

This is to certify that the thesis entitled “Biological Restoration of Urban Rivers in Changzhou- North River as case study” is an original and authentic work done by ZHANG Zhongyao in fulfillment of the requirement for the degree of Master of Environmental Science.

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## **List of Abbreviation**

GDP: Gross Domestic Product

MFM: Material Flow Management

COD: chemical oxygen demand

BOD: Biology Oxygen Demand

TN: total nitrogen

TP: total phosphorus

SS: suspended solid

## **Abstract**

Biological restoration of urban rivers becomes a trend for solving problems caused by fast economic development of China. The paper describes in details the process of biological restoration of North River as a case study in “Changzhou urban river clarification project”. Data analysis is made to see changes and trends of the dynamic process of North River and also the operation of biological system on the river. Furthermore, compare experiment makes it easy to select plants with high efficiency. The conclusion gives that in the future, with the better plants selection, rotation and optimization of living creatures, biological system could achieve better effect on river purification.

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# Chapter1 Introduction

## 1.1 background and overview of the paper

The implementation of the policy of “reformation” in China, which starts in 1978, booms Chinese economy dramatically, resulting in advanced economic development, fast industrialization, massive urbanization. Also people’s living standards are raising during this period. Along with new countless factories, millions of mansions and hundreds of thousands of buildings, the urban river ecosystem is badly degraded, due to “increasing disturbances, such as dam building, water resources exploitation, water allocation, meander cutoff, river branches building up, riverbank solidification and riverside vegetation destruction, disturb river flow regime and water cycle process”<sup>1</sup>. The main factor among the problems is the water pollution from the industrial water and the municipal water. Large amount of phosphorous and nitrogen is released into rivers, resulting in rich nourishment exaltation as well as algae increasing. Urban rivers become unhealthy, lose their color, turn to be stinking, its living species are killed by the pollution, the smell affect surrounding residents, meanwhile black rivers destroy the image of cities (figure1.1 shows the black and smelly image of urban river results from industrial pollution and municipal water), which is a big consider of our government.

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<sup>1</sup> Y.W.ZHAO, Z.F.YANG, F.XU; Theoretical framework of the urban river restoration planning; Environmental informatics archives, Volume 5 (2007), 241-247, EIA07-026, ISEIS Publication Series Number P002



Figure 1.1, Polluted urban rivers, source: Changzhou Environmental Protection Science and Technology Development Center

To solve the problem and to cure the sickness of urban river, government has tried their best, but still did not achieve river's health, which is combination of biological, economic and social functioning<sup>2</sup>. Traditional way of solving urban river problem is to “increase the capability and safety of the water supply and release by keeping the river course straight, enlarging the river breath, digging the river bed and hardening the river shore”.<sup>3</sup> The most famous example is Beijing “Jingmi Water Transformation Project”<sup>4</sup>. However urban river totally lost its natural characteristics as well as potential economic and social benefits in these old methods. Results deviate from the purpose.

New methods are expected to solve the urban river pollution problem while bring more additional benefits. “Since 1990’s, after learning experience from Japan, America and Australia, Chinese government starts to consider about the value of urban river ecosystem biodiversity and

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<sup>2</sup> LIU Heng, TU Min; Initial Understanding of River Health in Foreign Countries; Water Conservation of China, 2005,(4)

<sup>3</sup> ZHU Chendong; Ecological renovation of river course in Beijing; 5/2003, Beijing City Planning and Construction Review, page61

<sup>4</sup> WU E-nuo, CHE Yue, ZHANG Hongwei, YANG Kai; Urban River Regulation, Past, present, Prospects; Water and Wastewater, Vol 24, No.4, Feb 2008, page13-18

landscape.”<sup>5</sup> As an attempt, couples of cities in China start to restore urban rivers in a new way which is ecological restoration: plantation along the river bank, instauration of river’s natural curves and livings, water cleaning, building diverse landscape, etc, after which, damages on natural system caused by human activities are recovered<sup>6</sup>, city images are largely improved, environment become more pretty, attracting more tourists; living conditions of residents are far away from impact of smell, indicator of residential happiness raises; the prices of the land and the building around the riverbanks increase, construction industry then has more vividness. In fact, biological restoration rather than traditional way has high efficiency in cleaning water and becomes a trend in China’s history of coping with urban river pollution problems.

Changzhou as a well developed middle city, located in east part of China, soon or later, would follow the revolution road of the ecological restoration of its urban rivers, to solve the river problem caused during the economic development that suffers the city since the beginning. Actually the fact proves the trend. Year of 2008 witnesses the start of a big long-term project called “urban river clarification” project in Changzhou, which covers sixty urban rivers and more rivers will be included, in order to clean all of its urban rivers, giving back color to the nature in Changzhou city.

As an intern in Changzhou Environment Protection Science and Technology Development Center, which is the pioneer of this city’s “urban river clarification” project, author involved in some of the work for urban river ecological restoration and also witnessed the effort

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<sup>5</sup>ZHU Liang, MIAO Weihong, YAN Ying; Rivers and Lakes Bioremediation and Ecological Restoration Technology Review [J]; Hohai University: Natural Science, 2005( 1) : 20- 23

<sup>6</sup> Liao Wengen, Du Qiang, Tan Hongwu; Water ecological restoration technology application and development trends; water conservation of China, 2006( 17) : 25- 28Read phonetically

of human being to cope with the urban environmental problems. In this paper, author tries to describe technically, theoretically and practical this ecological restoration project in Changzhou city, which leads to better urban rivers and better environment. By using a river (North River) as case study, this paper tries to analyze the regular pattern of operation, advantage and weakness of ecological restoration in the practical situation. In the next chapter, author will introduce the specific “urban river clarification” project in Changzhou, how many rivers are involved, the goal, meaning, technology, and the overall process of the project (including related steps beside biological restoration). In one word, a macro picture of the project will be presented in that chapter. In the third chapter, we use one specific river which called North River, as case study, each component of the ecological restoration technology, each step of building the ecological system, how the function of each part plays role in solving the problem of North River will be described in detail in this chapter. Rather than second chapter that presents macro perspective, third chapter provides readers another choice so that they can see the project on a micro level. In the chapter fourth, data of North River (period within one day, period within nine days and period within two years) will be analyzed here to show the regular pattern of North River, to find out the factors that affect water quality, to describe the operation of biological system. Several diagrams are made here to compare the water situation in different time at different locations, also curves in the diagrams will present the dynamic process of the change and trends of water quality of North River, compare between river situation before and after the project will be made. Weakness and suggestions for improvement will be given in the end. The next chapter compares several absorption efficiencies of plants that are often used in our project, in order to give advice of plant selection for optimization of our biological system. In the last but not least chapter, the

paper will collect all the essential points from each section to build a conclusion and a vision for future will also be included.

## **1.2 Methodology**

In this paper, most of the knowledge, pictures, and data are provided by this institution- Changzhou Environment Protection Science and Technology Development Center- where author has worked for several months. A lot of material is developed by the relative company such as Zhejiang Tianyun Co, Ltd and Tsinghua University which involved in the project, too. Field study is also made to see the specific devices, urban river environment and how the system works. Author also read the material from internet and library about the ecological restoration technology to understand the system functionality and each step. The data in chapter four is monitored and collected by both the institution of Changzhou Environment Protection Science and Technology Development Center and Tsinghua University in a reliable and scientific way, finally analyzed by author, also the data of chapter five, that is measured and provided by Changzhou Environment Protection Science and Technology Development Center.

## **Chapter2 Changzhou “Urban River Clarification” Project**

### **2.1 Description**

Located in east part of China, which is the pioneer of economic development since 1978, the city Changzhou is an advanced industrial and well urbanized area. GDP (Gross Domestic Product) lists on the top part of most cities and the life standard of the residents are much improved. However, economic is much considered rather than environmental issues during this fast economic development, the urban environment is largely degraded. Environmental problems, such as sounds pollution, urban river pollution, air pollution, results from the economic development, start to affect people’s life standards. Current government is aware of the situation and making effort on solving the problem. Cleaning unhealthy rivers is one of the measurements. In 2008, Changzhou government starts its “urban river clarification” project to cure the sickness of the unhealthy urban river.

In Changzhou, urban rivers are badly polluted by the wastewater from the factories and residents along both sides of the riverbanks. The water contains large amount of phosphorous and nitrogen, resulting in rich nourishment. Many years’ accumulation of pollution leads to the contaminated river bed, which keep releasing chemical material into the up-water. Low dissolved oxygen causes that the rivers lost self purification capability. Dead rivers become black. Smell comes from organic debris and dead body of aquatic living or plants. The goal of “Urban rivers clarification” project made by our city is to give rebirth to these rivers, to clean the water, to establish water ecosystem, to give them the capability of self purification and pollution resisting.

### 2.1.1 Changzhou water system

Changzhou water system includes Ge Lake, Tai Lake, Beijing-Hangzhou Chancel, (circled by red line) connected by two hundreds of rivers. Figure2.1 is the map that shows the Changzhou river system, Ge Lake is on the left side of the picture circled by red line, Tai Lake is on the right side of the picture, circled by red line, Beijing-Hangzhou Chancel is on the up side of the picture circled by red line and all of the urban rivers are located on the top of the picture circled inside violet color. river is blue curve in the picture.



Figure2.1, Changzhou water system, source: Changzhou Environmental Protection Science and Technology Development Center

Figure 2.2 is a zone in picture of the violet area in figure 2.1. All of the urban rivers that covered by the “urban river clarification” project are within the picture. The area circled by red is urban area of Changzhou, the urban rivers are marked by blue lines, the ones that are included in the project are deep blue ones and most of them within urban area (inside the red circle). To list their names here to better understand the project. They are Laozao West Subsidiary River, Phoenix river, Caizhi Strand, Laozao River, Laozao East Subsidiary River, North Tongzi River, Sanjin River, Beitang River, Wukui Bridge River, Twin Bridge River, Hejia Pond, North Hentang River, Maolong River, Golden Boy River, Haishikou River, Maolong River, Dawan Strand, Tongqi River, Cuizu Inland River, Qingfeng Strand, Hentang River, Tongxin River, Xihandong River, Guan River, North River, Hongmei Inland River, Mijia Pond, West River, Suoqiao River, Cross River, Hongzhuang River, Huiguan Strand, Shengjia Strand, Zhongliang Strand, East River, Houtang River, Xujia Strand, Yejia Strand, Zhangjia Strand, Thirty-eight River, South River, Xiaocang Strand, Baijia Strand, Liutang Strand, South Golden Boy River, Baidang River, Sanbao Strand, Jiangjia Strand, Huangliang Strand, Youlong River, Qianlang Strand, Changfeng River, Jichang River, Chenchu River, Huang River, Phoenix Strand, Mi River, Lotus Harbor, 21 Meter River, Wind Around River, Meigang River). The urban river clarification project starts since 2008, however, more new rivers will be included every year because that the project of restoration is a continuous process. What’s more, Old rivers still need maintenance so that they are still included in the next year’s list. As a conclusion, the deep blue lines actually will increase every year. The river circled by the yellow mark in the middle of the urban area is North River, the one that will be the case study in chapter four. In Chapter three it will be described in details.

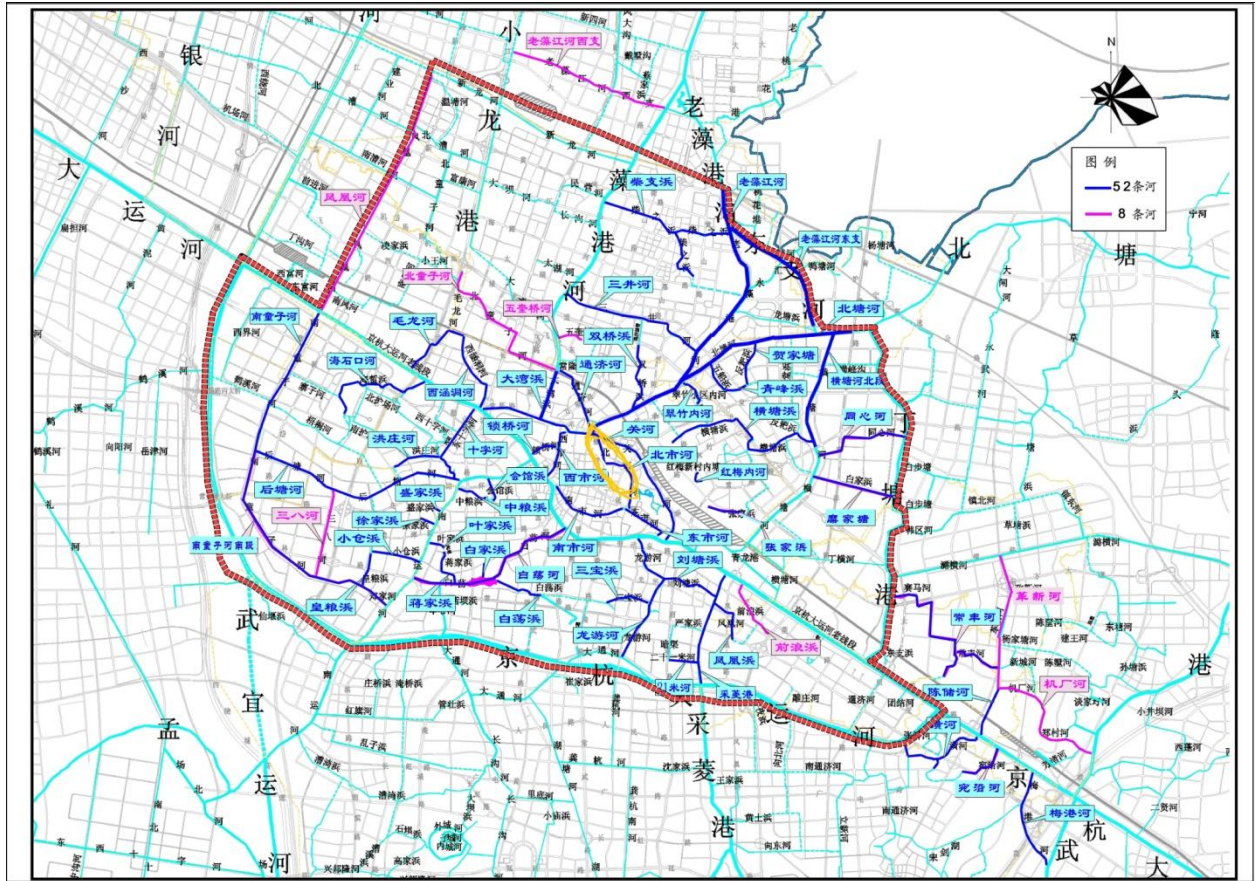


Figure2.2, urban rivers in Changzhou, source: Changzhou Environmental Protection Science and Technology Development Center

## 2.2 meaning of clarification project

Urban rivers as blood vessels of the city, provide close water resource, reduce urban heat island effect and floods, improve city landscape and biodiversity, connect human and nature and create space for entertainment. There is no doubt that urban river has influencing function and plays a big role on daily city life. Before the clarification project, all these functions of urban rivers mentioned above are lost through the fast economic development, industrial and municipal wastewater and residents' ignorance. In order to recover city's spirit, which is the coincident the

goal of our clarification project, Changzhou government finds the necessary of recovering the functions of the urban rivers.

### *2.2.1 Benefits of the project*

The clarification project actually covers social, economic and ecological benefit at the same time, which is balanced between these three points. In social perspective, clarification project turns black water into transparent as well as reduces smell of the river, which improves the city living environment and landscape. Butterflies and birds are attracted around the rivers by better environment. The different alive sounds from the creatures combine with variable color of the flowers and plants together play a song. Living conditions of residents become better and they even choose urban river as one more choice for entertainment and leisure time.

What is more, clarification project has ecological benefit. After improvement of water quality and aquatic living condition, some creatures can survive at the bottom of the river. With plants on the floating island and wetland, fishes, they together can build a sustainable ecosystem, a positive circle, so that urban river can resist pollution and purification by itself, based on the artificial food chain.

Economic benefit of this project is very high, also cannot be underestimated. The increased land price and better investment environment brought by the project will attract more cash flow, stimulate local tourism and speed economic development. The financial cost for annually traditional handling the smelly black river problem could be saved and transferred to

other area. The economic plants on the floating island, such as water iris, canna and reed, with reasonable and theoretical guide can produce market demand and economic income.

### *2.2.2 Perspective of MFM (material flow management)*

On perspective of MFM, we recommend to reduce material input as well as material output of any independent system. It is always necessary to optimize the process of the system so that positive circle will be built and function by keeping usage of inside resources within the system boundary. Added value can be created during this process.

In our urban river ecological restoration project, MFM is well implemented as readers will see in next chapter. Under traditional method, there are annually large amount of financial cost, energy and resources, human efforts input into the urban river system (the boundary is the river itself) and black river phenomenon and smell as output from the system. But in this project, most of the costs are reduced or eliminated.

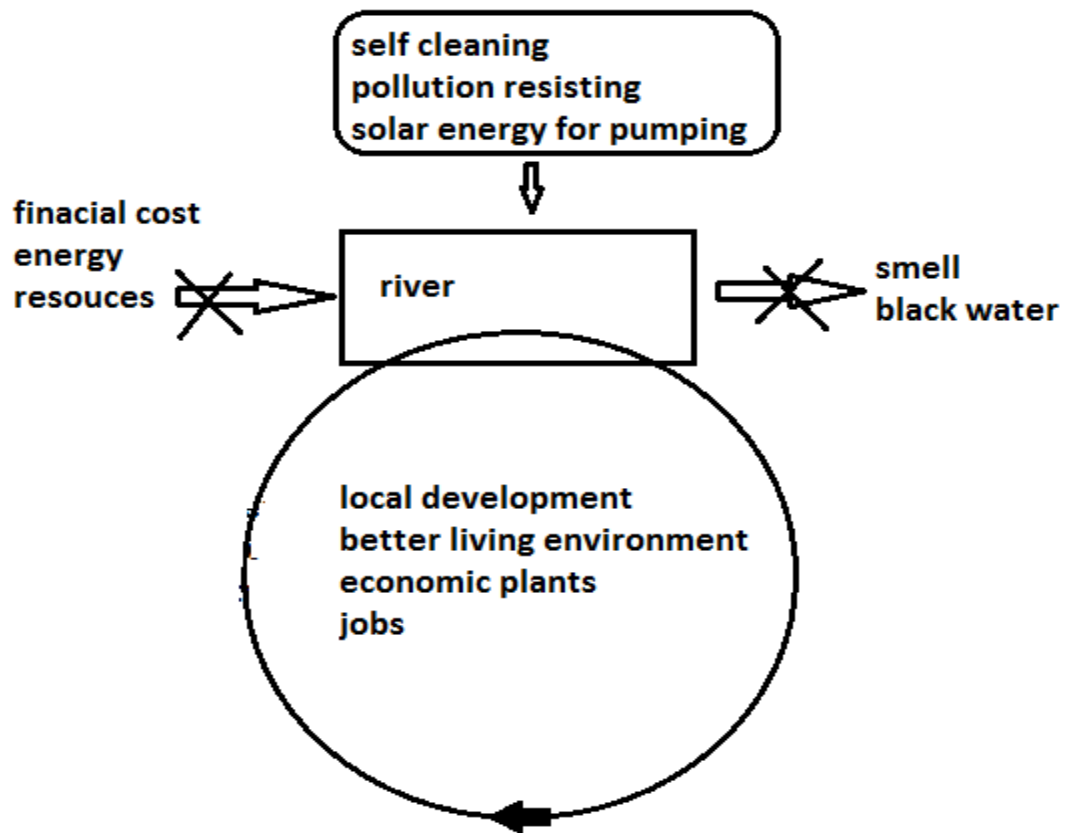


Figure 2.3, biological restoration on MFM perspective, Source: ZHANG Zhongyao, IMAT, Ritsumeikan Asia Pacific University

Clarification project is to build an ecological system inside the river to achieve river' capability of self cleaning and pollution resisting, so that outside input (financial cost, energy resource and labor) can be reduced as well as output (black and smell water). The river can become clean and not black and smell anymore. This project also contain added value at local area. First of all, because that the system needs daily maintenance such as cutting plants, oxygen pumping, etc, jobs for maintenance are created. Furthermore, solar system is built to provide the electricity of oxygen pumping. So no extra energy is input into the system. What's more, these

economic plants on floating island and wetland can enter into the market, achieve economic value. Last but not least, better environment bring better living condition and better local development. In one word, this project closed the material loop, achieves zero emission (Peter Heck).

## **2.3 Clarification project process**

### *2.3.1 Eliminate pollution source*

The original causes of black smelly river are industrial and municipal wastewater around the river. At the beginning of our project, it is necessary to take efforts to regulate the factories along the river, so that the release pollution can be under certain standard. For those which illegal release wastewater, government forced them to leave this area. Until 2010, the number of wastewater discharge of this river is reduced from 582 into 281. Municipal wastewater is reduced by 35700 ton each year. Industrial wastewater is reduced by 23600 ton each year. Based on less pollution discharge, with its proper purification capability, biological system will bring very clean water to urban rivers.

### *2.3.2 Wastewater interruption by parallel pipes*

Agriculture wastewater and municipal wastewater enter into the river as well as the pollution along with the rainwater. Interruption is made to stop the wastewater directly polluting the river. Parallel pipes are made along the river to collect water which will directly come into the river.

### *2.3.3 Dredging through*

Different rivers are connected in the step, so that water flow can move, keep alive, water oxygen contain can increase. It is an important foundation for next step.

### *2.3.4 Biological restoration*

This is the most important step, build sustainable ecosystem inside the river to achieve river self purification. We use floating island, wetland, aquatic living and fishes to establish a complex system in order to continue a positive circle.

### *2.3.5 Monitor*

After build the system, regular monitoring of the water quality is still very important to warn and solve problems in the future. By monitoring water from different positions, we can know whether system is working well, what is the reason if the system is abnormal, how to solve the problem.

### Chapter3 ecological restoration of urban river

In this chapter, author use North River (marked by yellow circle in figure 2.2) as case study to describe the whole process of building artificial biological system in clarification project by Changzhou Environment Protection Science and Technology Development Center, including each step of the process in details and every component involved, etc.

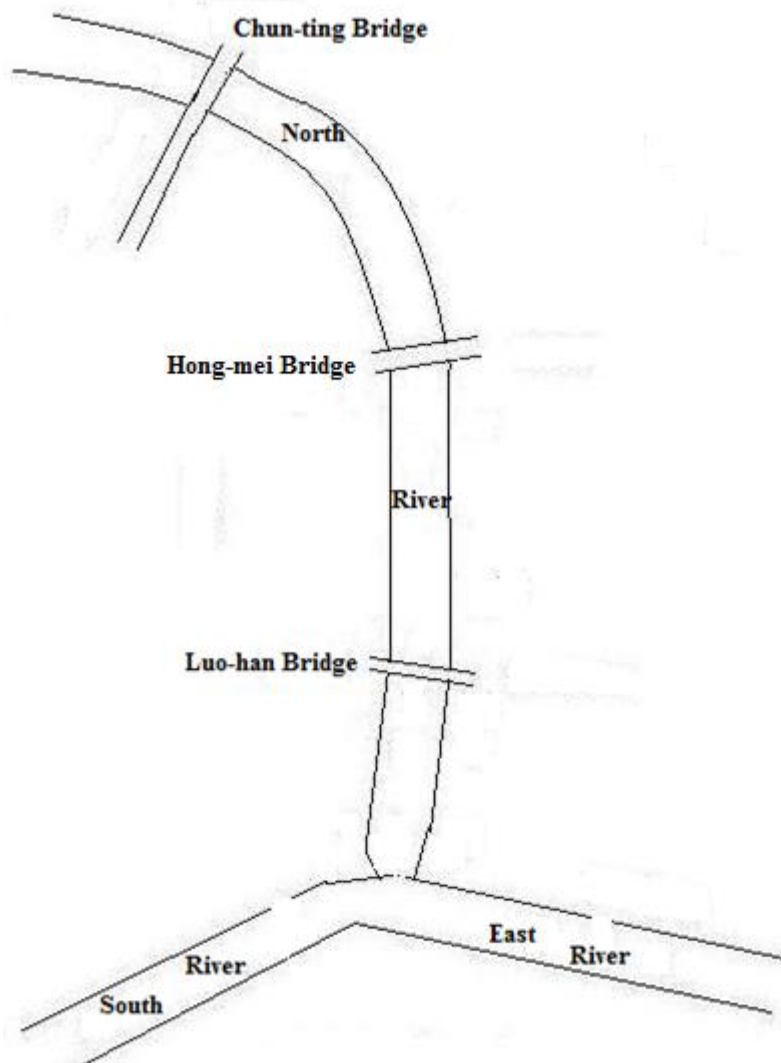


Figure3.1, North River, source: Changzhou Environmental Protection Science and Technology Development Center

### **3.1 Introduction of North River**

#### *3.1.1 Climate, hydrological characteristics*

Changzhou, which located at the southern margin of the north sub-tropical, belongs to monsoon climate. It has four distinct seasons, with longer winter and summer, shorter spring and autumn. The city is crossed by Beijing-Hangzhou Grand Canal (as showed in figure2.1), meanwhile fulfilled by intertwining water network. The mean temperature is 20.2 C degree. August has the highest temperature which is 32.2 C degree average. January has the lowest temperature, which is -1.6 C degree average. Changzhou has abundant rainfall. Annual rainfall can achieve average 1036.1 mm. In September, when the rainfall amount is in its peak, can reach 15% of total annual precipitation. In winter, the wind blows from northwest to north, in summer the wind blows from east to southeast, the whole year is based on east wind. There are some climate disasters such as drought, wind and flood.

#### *3.1.2 The basic situation of North River*

North River located in Tianning district of Changzhou city, from Chun-Ting Bridge in south, until West Village in North. Two side of the river is built by concrete. The river is about 2 to 3 meters depth, less than 15 cm transparency, 16 meters wide, covering about 24,000 square meters area, the river is about 1500 meters long from Chun-ting Bridge until the junction between East River and West River, which is showed in figure3.1. Northern part of North River, which is from Chun-ting Bridge to Hong-mei Bridge, is more polluted than southern part and has more seriously black and smell phenomenon because of direct or indirect industrial discharge and sewage water from residents. Southern part of North River is from Hong-mei Bridge until the end of North River. North River usually has no water flow, only adjusted by a pump station.

In summer, seasonal water bloom occurs, companying with black-odor phenomenon along the whole river. No high aquatic plants or animals are living inside the river, except some small miscellaneous fish. The table3.1 below shows the water quality status of North River from 2009 to 2010.

### 3.1.2.1 Water quality status

The river is monitored from 2008 to 2009 by Changzhou Environmental Protection Science and Technology Development Center during the survey and evaluation of ecological environment in Changzhou, the data of the water quality is as follows:

Project analysis (average)	Standard value ( level V )	North River (average)	
PH	6~9	7.27	standard
Dissolved oxygen	$\geq 2$	1.21	exceed
transparenc (cm)		15	
Standard of Chemical demand	$\leq 40$	33.71	standard
Nitrogen	$\leq 2.0$	4.58	exceed
Phosphorus	$\leq 0.4$	0.60	exceed

Table 3.1, water quality of North River, source: Changzhou Environmental Protection Science and Technology Development Center

Basic projects of surface water quality standard unit: mg/L

project	I	II	III	IV	v
ph	6~9				
dissolved water contain ( $\geq$ )	7.5	6	5	3	2
COD ( $\leq$ )	15	15	20	30	40
NH <sub>3</sub> -N ( $\leq$ )	0.015	0.5	1	1.5	2
TP ( $\leq$ )	0.02	0.1	0.2	0.3	0.4
TN ( $\leq$ )	0.02	0.5	1	1.5	2

Table 3.2, surface water classification, source: “surface water quality standard of People Republic of China”

According to “surface water quality standard of People Republic of China in 2002”, water of level I is for source of water, for example, the National Nature Reserve. Water of level II is for centralized drinking water in surface sources protection zones, such as aquatic habitat, origin of fish and shrimp. Water of level III is for centralized drinking water in surface sources protection zones, such as water for fish farming or swimming. Water of level IV is for industrial use and no direct human contact water. Water of level V is for agriculture and landscape.

In table 3.1, we can see that except average COD (33.71) indicator of North River reaches the standard (less than 40), other indicators are all worse than the water of level V standard. Average dissolved oxygen of North River is 1.21, less than the standard of at least 2. Average nitrogen is 4.58, much larger than the standard of 2.0, phosphorus is 0.60, larger than standard of 0.4. According to the relevant river water quality and water quality monitoring

results, we can see that the value of river dissolved oxygen, value of ammonia nitrogen, value of total phosphorus are worse than water class V standard, which means the water quality is really bad, North River is highly polluted. So effort to clean the water and restore the river is necessary.

#### 3.1.2.2 Characteristics of sediment

Bottom structure of the river is muddy sediment. The main pollutants accumulated in sediment are garbage deposits and leaves. In northern part of North River, the soil is seriously contaminated because of large amount of organic pollution accumulation results from long-term wastewater from industry and residents (there are three outfalls in this section), dust along with rainwater, soil erosion, dead algae, etc. The sediment of northern part of North River keeps releasing organic material, which is beyond the capability of aerobic metabolism of microorganism inside the river.

#### 3.1.2.3 Preliminary investigation of biological status

Cyanophyta was the dominant species of phytoplankton in the river channel, dominant specie of zooplankton is *Strobilidium gyrans*. There is no high level plants, also no high level aquatic animals, due to high pollution and the low oxygen dissolved contain in the river.

#### 3.1.2.4 Analysis of pollution sources and pollution

The source of pollution is long term accumulation from dead stems, leaves and algae and waste water from industry and residents living in both sides of the riverbanks. The bottom sediment of North River is mostly fulfilled with organic pollutants. With the exchange with up water, the sediment keeps releasing high concentrated pollution. Surface pollution is rainwater

(ground contamination settlement, municipal wastewater and other pollutants are carried by rain runoff into the river). Point sources are municipal wastewater, pumping replenishment, municipal sewage overflow, wastewater of restaurants, cars repair. Main waste sources are residential garbage, construction waste, sediment and decaying floating materials.

#### 3.1.2.5 Goals to achieve

“Clarification of urban rivers” is the project government uses to better urban environment, to benefit citizens and to improve living conditions and image of our city. North River (from Chun-ting Bridge to Luo-han Bridge), as one of important rivers across the center of the city, no doubt is included in the very first targets in the restoration project. The project lists the goal of restoration of North River as follows:

1. Water transparency, 30-40cm, clean surface, no algae, no color, no black and odors.
2. COD achieves surface water class standard IV. Dissolved oxygen increased by 25% to 30%; ammonia nitrogen removal rate of 20% to 30%; total phosphorus removal rate of 30% to 40%.
3. Project use coin grass, poly grass, reed, bamboo mosaic, iris, yellow iris, force flower, canna, etc, to realize water and vegetation restoration, so that North River has its living biodiversity, sustainable plants population, warm season plants and cold season plants can replace each other.
4. Achieve water landscape objectives. Improve landscape and green without affecting the natural environment. Use aquatic plants, hydroponics plants, land plants to build landscape with the match with the plants on the both sides. Combine practical and

ornamental, strengthen surface landscape on the bridge and junctions. Human, nature and ecology as principle, build natural, ecological and harmonious style of landscape. Build certain landscape that one year has four green seasons and spring, summer and autumn flowers. Form a pretty picture by Integrating coastal landscape and water reflection.

### **3.2 concept description of biological restoration**

The paper mainly discusses the biological restoration of the project. To understand that, it is indispensable to introduce the main concept of urban river restoration first. Biological Restoration is the process of increasing living creature diversity of the river in order to build a complete and complex ecological environment inside the river, which achieves a positive circle and sustainable system that enables river to resist pollution and clean by itself<sup>7</sup>. Figure3.2 is the picture of one complete biological system. It shows the structure, relations between different components of the system and also how it works.

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<sup>7</sup> Rijs, W, Lindmark, G; Ecosystem control by nitrogen metabolism in sediment; Vatten, 34: 135–144.

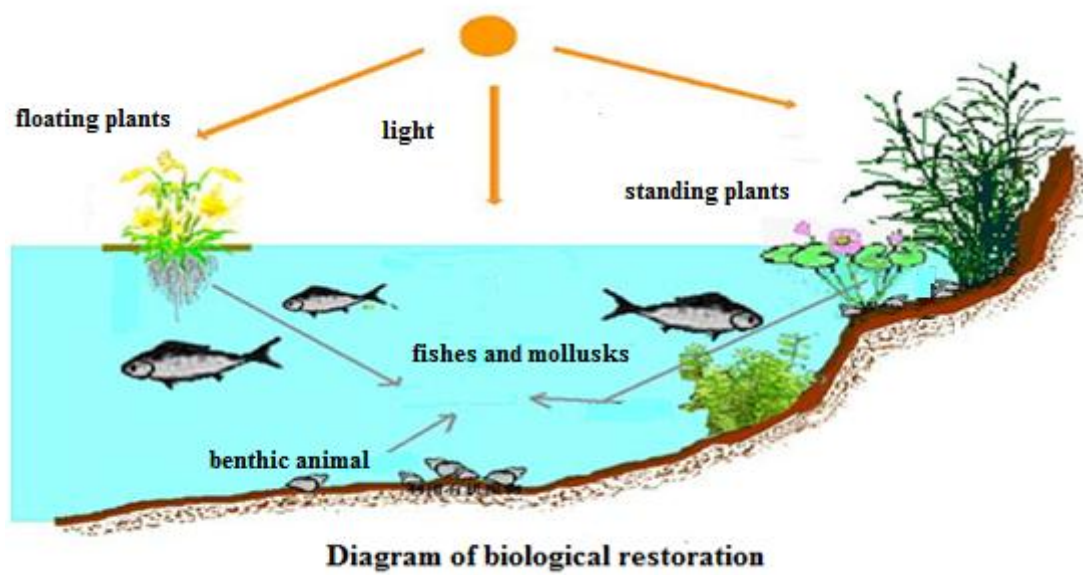


Figure3.2, concept of biological restoration, source: Changzhou Environmental Protection Science and Technology Development Center

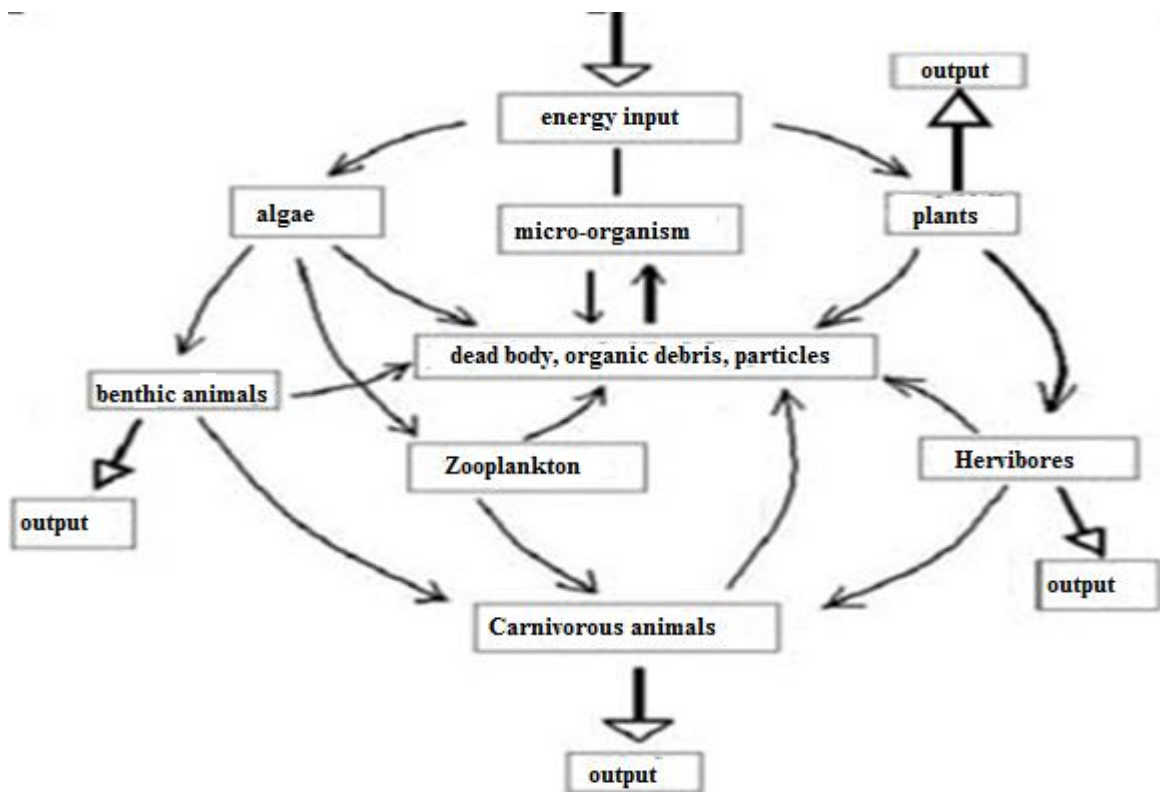


Figure3.3, food chain of system, source: Changzhou Environmental Protection Science and Technology Development Center

At the bottom of the river, benthic animals are living based on the organic material degraded from the soil by sediment modifier (it will be mentioned in section 2.3.1). At the same time, they are also the food of fishes and mollusk raised in the higher level of the river. The moving of these creatures under the surface brings the air into the river which increases dissolved oxygen contain in the water. In the up level of the river, the system has floating plants and standing plants to play the main purification function of the system, which is absorbing nourishment such as nitrogen and phosphorous. Because eutrophication is caused by rich nitrogen and phosphorus in the river<sup>8</sup>, reduction of nourishment by the up system can lead to COD (chemical oxygen demand) reduction, bacteria elimating and black smelly phenomenon disappear. Cattail, iris, canna, mushroom, wild rice stem, cress are planted in the shoal area (near the bank), as well as Yong vegetables (water spinach), round coin grass, grass poly are planted in floating island (away from bank). Because of the suitable living condition in the surface area (abundant sunlight and warm temperature) as well as the food sources (fishes and mollusks), birds, amphibian animal and insect are attracted to live near the river. The birds dropping along with the fatty fish oil provide the food for plants' growth.

Variable creatures living in different level of the river establish a stable and coherent food chain which automatically to enable the sustainable operation of the system. (The figure3.3 describes the system in a perspective of food chain. Energy input as sunshine comes into the system, is absorbed by the first level of creatures such as algae, micro-organisms, standing plants and floating plants. The primary food chain such as algae, micro-organisms and plants then become organic debris, suspended particles and dead body which are food source for next chain

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<sup>8</sup> Howarth R W, Marino R. Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: evolving views over three decades, *Limnology and Oceanography*, 2006, 51(1): 364-376

creature such as benthic animals, zooplankton and Herbivores. The highest level is carnivorous fishes which eat benthic animals, zooplankton and herbivores.) By circulation of this automatic natural system, the river is able to repair by itself and keep pollution in a certain level.

### **3.3 The process of ecological restoration**

After understand concept of the biological system, each step and each component of the building the system is going to be discussed in this section. Figure 3.4 shows roughly the establishment process of the biological system. 1. We first build biological grid to pre-treat the wastewater from point pollution and source pollution. 2. Sediment at the bottom of the river is degraded by chemical material so that continuingly pollution from the contaminated soil could be stopped. 3. We build floating island and wetland to absorb nourishment such as nitrogen and phosphorous as well as eliminate virus and black smelly phenomenon. 4. Aquatic creatures such as fishes, mollusks and benthic animals are put into the river to establish a complete food chain. 5. After adjustment of the living creatures in the river, the sustainable positive circle is established. 6. The system also needs maintenance such as plants cutting as well as regular oxygen pumping. The technologies used in building the system will presented after in details. However, according to the reality, different area of North River may have adjustment in process. For example, soil of southern part of the river is more polluted. More effort is need to put on soil degradation and tre-treatment of the source water by biological grid. In northern part of river, because of better condition, maybe floating islands and floating wetlands have more impacts.

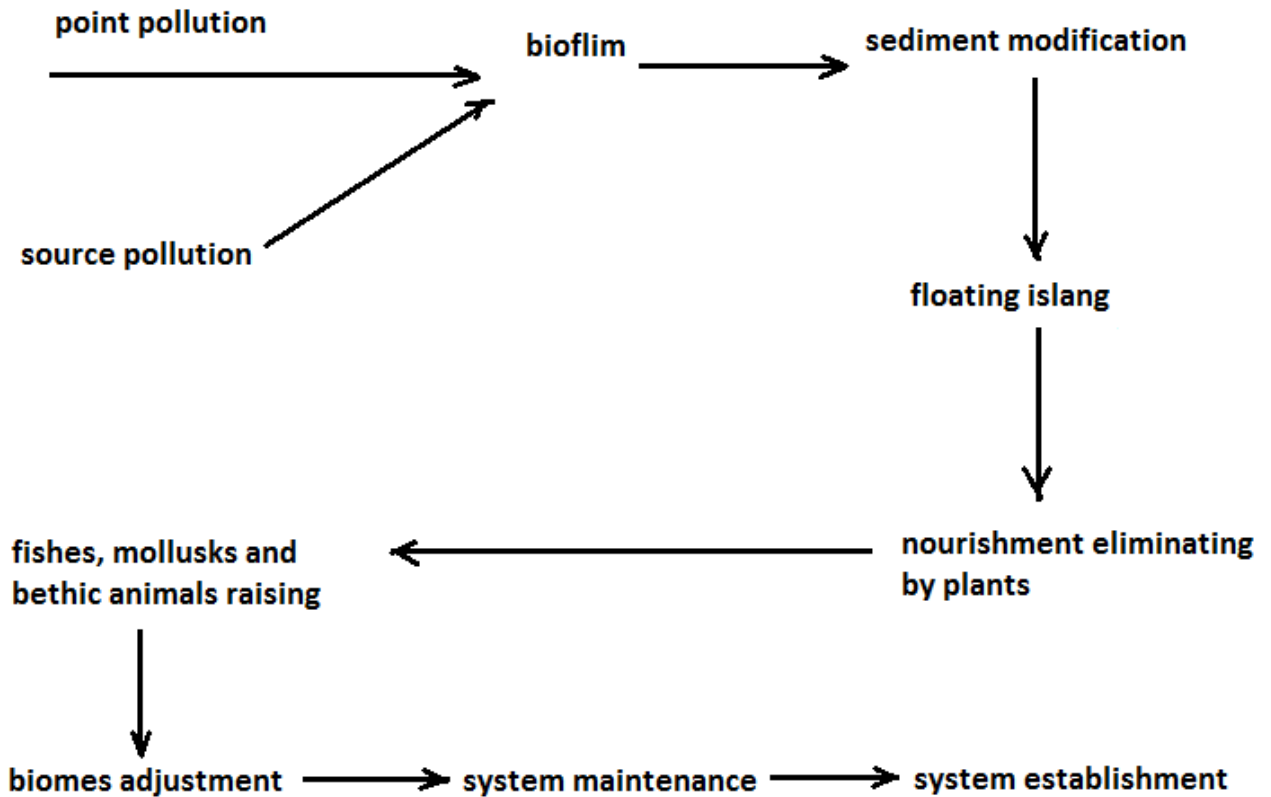


Figure 3.4, process of biological restoration, Source: ZHANG Zhongyao, IMAT, Ritsumeikan Asia Pacific University

### 3.3.1 Sediment degradation

Contaminated sediment at the bottom of the river becomes a constant cause of river's black and smell phenomenon, continuously releasing high concentrated pollution into the upper water. In the project, by using microbial technology, we stopped the pollution source, cut the nitrogen, phosphorous and carbon circle in the water and improve organic matter insider the sediment in order to build the foundation for the growth of aquatic plants.

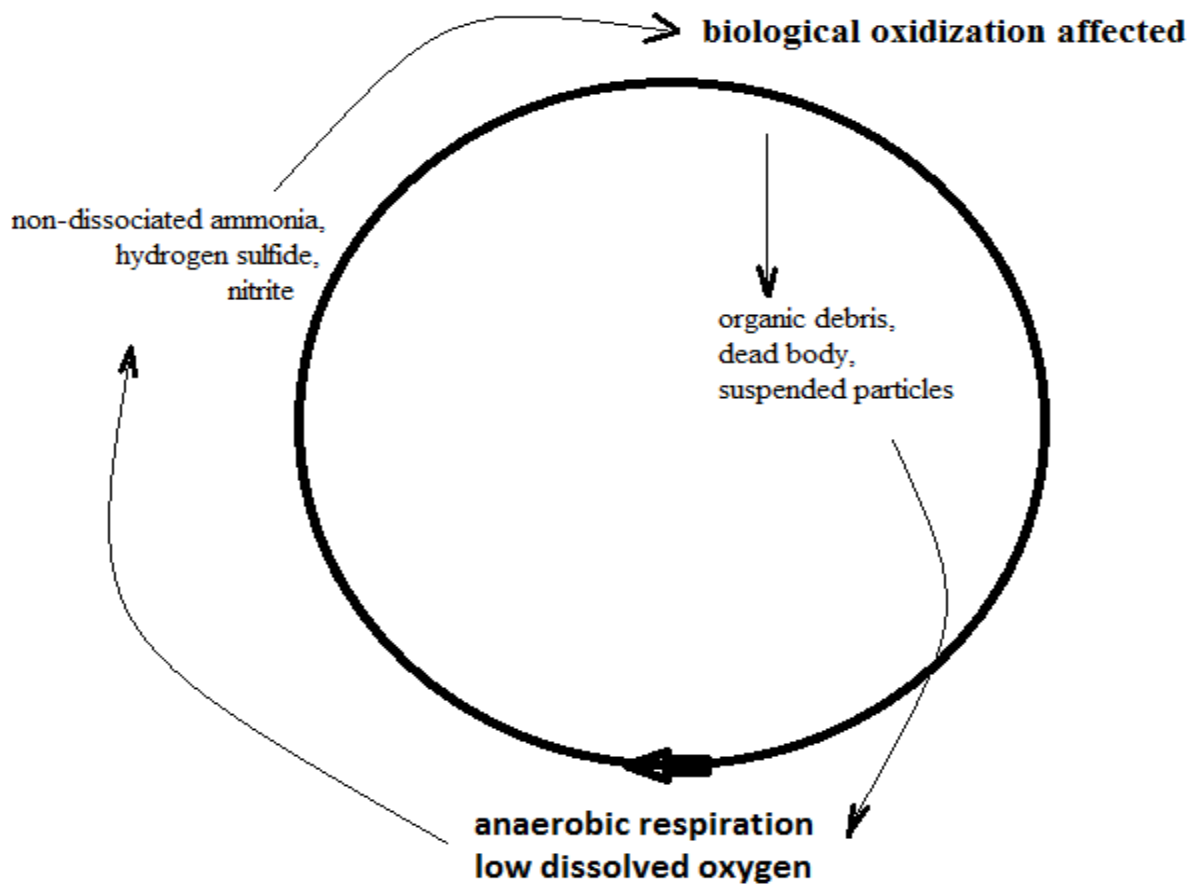


Figure3.5, Vicious circle, source: ZHANG Zhongyao, IMAT, Ritsumeikan Asia Pacific University

Through long-term atmosphere deposition, wastewater from industry and residents, dust along with rainwater, soil erosion, dead algae, etc, large amount of organic pollution is accumulated in sediment at the bottom of the North River (especially southern part of the river). The contaminated soil keeps releasing organic material, which is beyond the consumption

capability of aerobic metabolism of microorganism inside the water. “Oxygen consumption and mineralization of organic matter result from coupling between nitrification and de-nitrification.”<sup>9</sup>

Excess degradation consumes too much oxygen at the bottom level leads to hypoxia. At the environment where dissolved oxygen is less than 0.2g/l-0.3g/l, anoxic bacteria and anaerobic bacteria start anaerobic respiration, which destroys biological oxidization process- that is the foundation of water self purification.

Without enough oxygen, as a result of anaerobic respiration, hydrogen produces toxic substances, such as non-dissociated ammonia, hydrogen sulfide, nitrite, etc, which also affects oxygen and river self purification capacity in the upper water level. Living organism, biodiversity and as well food chain loses in this situation.

Meanwhile, organic debris, dead body and suspended particles results from the death of living organism of upper water, in turns aggravate anaerobic respiration in the lower water level. On the base of this continuingly vicious circle (described in figure3.5), the river becomes black and odor.

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<sup>9</sup> Ripl, W. & Lindmark, G. (1978). Ecosystem control by nitrogen metabolism in sediment. *Vatten*, 34, 135–144.

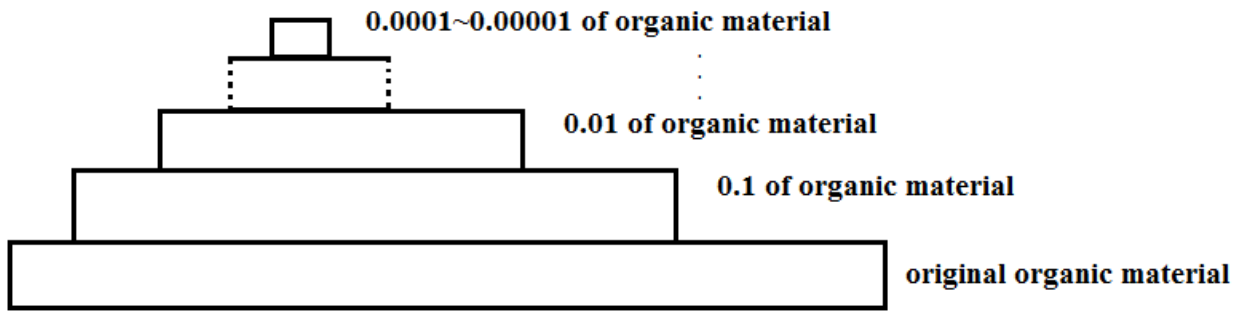


Figure3.6, sediment degradation, source: ZHANG Zhongyao, IMAT, Ritsumeikan Asia Pacific University

To stop the vicious circle, contaminated source has to be eliminated very first. In this project, we use the technology of sediment modifier, to degrade the sediment organic pollution. First of all, the mixture of acid hydrogen peroxide and calcium peroxide are put into the bottom of the river to increase dissolved oxygen. “The mixture of hydrogen peroxide and calcium peroxide can provide electro acceptor during organic degradation”<sup>10</sup>, in case the oxygen pumping does not work very well. Then sediment modifier is put into the sediment to rebuild the destroyed biological chain- scavenger food chain at the bottom, which is the very important foundation for recovery of the upstream biological food chain and mineralization of the sediment. In this process, the organic material chain is gradually shifted to higher level food chain (as showed in figure 3.6), during which only about 10% of the organic matter become biological organism and the left 90% become water, carbon dioxide, other kinds of substances and released energy. In a general food chain, there is usually at least four, five levels’ living, and ultimately creature is only about one ten thousandth or one hundred thousandth of the original senior living organisms (in figure 3.6, it is clearly that the final organisms is far less than the primary

<sup>10</sup> The development of biological restoration of polluted water, Fangyan Chen, Yunbin Tang, Environment science and technology, 2004/27, 133136

organisms). By transferring from lower chain to higher chain, large amount of pollution is eliminated.

Sediment modifier, which is popular at aquaculture and water restoration industry, is made of photosynthetic bacteria, lactic acid bacteria, bacillus subtilis on the base of special process. With the use of zeolite powder as the adsorption matrix material, aerobic and anaerobic can exist together. The function of sediment modifier is to achieve nitrification and mineralization of the sediment by consuming organic material inside sediment. Because that the engineered bacteria has population decline with time, the impact of sediment modifier on the ecosystem is very small as well as the adsorbent material due to the fact it is from natural minerals.

Microbial technology basically is to degrade sediment, break down, converse, transmit and decrease organic pollution. After the whole process, the sediment become stable, no nutrients is released, and due to reduction of the organic matter, the volume and thickness of sediment are reduced.

### *3.3.2 pre-treat by biological grid and oxygen pumping*

Although continuously pollution from contaminated sediment is eliminated at the primary step, around North River, there are still many source pollution, point pollution and rain water pollution around, which affect water quality. There are rainwater (ground contamination

settlement, municipal wastewater and other pollutants are carried by rain runoff into the river), municipal wastewater, pumping replenishment, municipal sewage overflow, wastewater of restaurants, cars repair and also residential garbage, construction waste, sediment and decaying floating materials. In order to ensure a stable recovery of plants, all those source pollution, point pollution and rain water pollution should be controlled as well in the very beginning. In this project, we build measurements such as biological grid, oxygen pumping to pre-treat the rainwater discharge and sewage overflow. Because northern part of North River is highly polluted, biological grid and oxygen pumping is focused on this section.

#### 3.3.2.1 Biological grid

In the high nourishment concentrated water environment, lack of sunlight is a barrier for the growth of plants. However biological grid technology (figure 3.7 is the picture of how it looks in the reality), with advantage of large surface area, can overcome the problem of the lack of sunlight. Biological grid technology is to use pollution tolerant plants to build biofilm under surface water in order to reduce source pollution and improve transparency of the river. As figure 3.8, which is the function picture of biological grids, shows that pollution tolerant floating plants such as coin grass are planted up the surface water in river while to form grids under water surface by their roots. The biological grids under the water work as film to filtrate pollution as well as inhibit algae.



Figure3.7, biological grids in reality, source: Changzhou Environment Protection Science and Technology Development Center

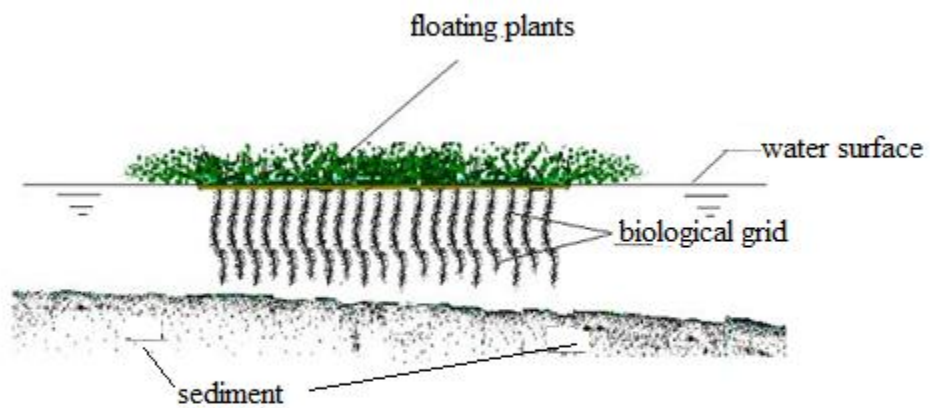


Figure3.8, biological grids, source: Changzhou Environment Protection Science and Technology Development Center

### 3.3.2.2 Oxygen recovery pretreatment

Dissolved oxygen content and the mobility of water are important for water purification capability. Increasing dissolved oxygen content in the water is the job of oxygen pumping. Oxygen pumping is to push flow, stimulate water circle, increase exchange between higher level water and lower level water in order to suck more oxygen into the water which leads to increase of water dissolved oxygen content. Increase of dissolved oxygen content will bring destruction of algae living environment, inhibition of algae bloom and achieve water self purification.

The device system we use in our project for oxygen pumping is plug-flow aerator, which is made of submersible motor, water impeller, mounting bracket (mounting points and submerged floating installation), suction chamber, suction tube, protection switches, etc. High-speed rotation of the water impeller have a strong thrust and radial mixing of axial force, which crushes air into air bubbles to create a strong flow of gas-water mixture, promoting a greater flow inside water as well as higher oxygen content. Organic matter, nitrogen and phosphorous are then reduced in a short time. There are twelve plug-flow aerators with power of 3.7kw or 1.5kw installed in North River.

Biological grids and oxygen pumping are usually installed near intake pumping station, sewage overflow, the combination of low-lying ground drainage system, where point pollution, source pollution, rainwater pollution exist. After passed oxygen recovery pretreatment and the biological grid, largely amount of COD and suspended solids are removed. When the pollution into the ecosystem is controlled and stable, biological plants technology such as floating wetlands and floating islands can be planted to replace biological grids plants.

In this system, solar modules are connected as an energy source. Couples of solar panels are installed along the riverbanks. So outside electricity that produced by fossil fuel is not taken into the system. The operation cost of the system mainly focuses on maintenance fee, labor and electricity. On the base that output electricity is eliminated, the total operation fee is largely reduced. Meanwhile extra electricity left over which is given birth by sunlight will be transferred to the national grid for regular use.

### *3.3.3 Floating wetland and floating island technology*

Based on the different absorption capabilities of nitrogen, phosphorous, variable floating plants and standing plants are raised in the river to promote water purification.

#### *3.3.3.1 Floating wetland*

Floating wetland is built on the floating bed, where functional micro-organisms are biofilmed in the portfolio composed by a certain percentage of substrate packing. We plant standing plants such as mosaic bamboo reed, wild rice stem, cattail, iris, yellow iris, canna on the floating wetland. Through a complex chemical biological process inside the plants, floating wetlands consume sunlight, CO<sub>2</sub>, O<sub>2</sub> and degrade nitrogen and phosphorous in the river<sup>11</sup>, the roots absorb nutrients as well as eliminate bacteria, which in turn reduce black odor phenomenon. At same time, plants can provide food for herbivorous fishes under the lower water level. The

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<sup>11</sup> Polomki R F, Taylor M D, Beclenberg D G, et al. Nitrogen and Phosphorus remediation by three floating aquatic macrophytes in greenhouse based laboratory-scale subsurface constructed wetlands; *Water, Air and Pollution*, 2009, 197(1-4): 223-232

filtration function of floating bed and the plants' capability of purification, together achieve purification function of wetlands.



Figure3.9, floating wetlands in reality, source: Changzhou Environment Protection Science and Technology Development Center

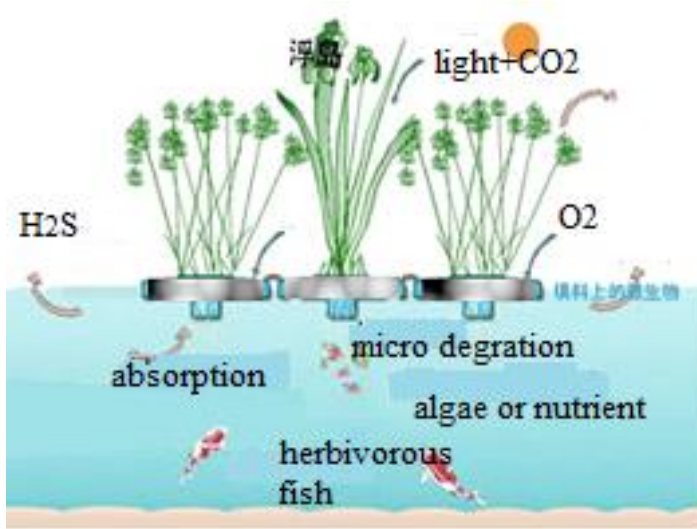


Figure3.10, floating wetlands, source: Changzhou Environment Protection Science and Technology Development Center

Figure 3.11 shows the material for making floating wetlands. According to the picture, floating wetland is made of wood Geocell, wood geogrid, nylon rope, foam board. The life period of these materials is usually between 8 and 10 years, with properly maintenance, they can last more than 10 years.

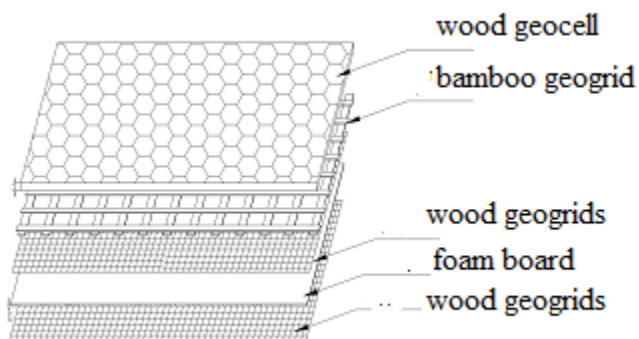


Figure3.11, material for floating wetlands, source: Changzhou Environment Protection Science and Technology Development Center

### 3.3.3.2 Floating island

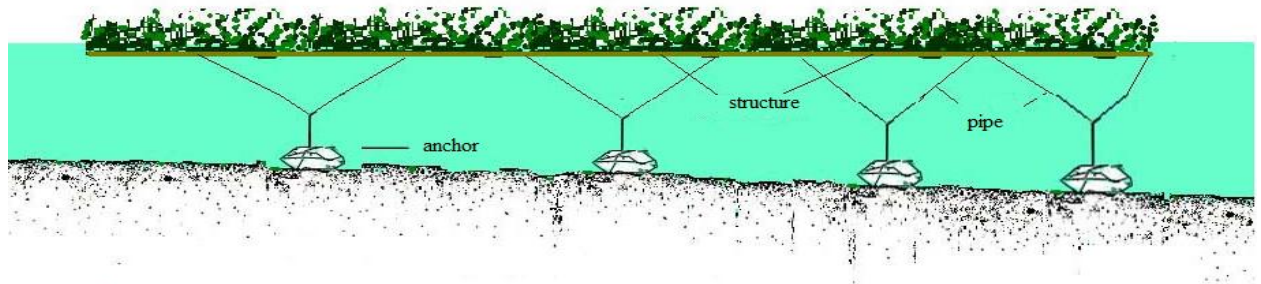


Figure3.12, structure of floating islands, source: Changzhou Environment Protection Science and Technology Development Center

Floating island is first created by German company Bestman for fish spawning in Biwa Lake of Japan. Then it starts to be used in projects of urban river restoration in Japan, in German and in American since 90's. In floating island technology, plants are put on the floating island, the roots absorb nutrients inside the water, meantime microorganisms on the roots of the plants form biofilm to clarify the water. Plants such as spinach and water peanuts (for warm season), round coins (for cold season), which have highly absorption rate are planted on the floating island to reduce nitrogen and phosphorous. In case the plants on the floating island grow out of control, there is also frame installed on the floating island to prevent bloom of the plants.

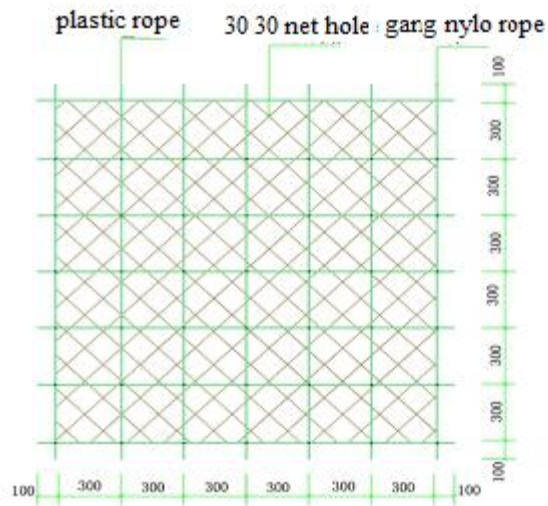


Figure 3.13, carrier of floating island, source: Changzhou Environment Protection Science and Technology Development Center

For floating islands, keel is made of bamboo keel while carrier is made of fishing nets, which make that the framework of floating island has strong mechanical properties and is able to last 3 to 5 years. Furthermore, the floating island is made of non-toxic organic polymer materials so that it is not harmful to the environment. Figure 3.13 shows floor plan of the floating island, the net hole is 30mm multiply 30mm, space between plastic rope and plastic rope is 30mm, gang nylo rope is made as main structure, the space between gang nylo ropes is 300mm.

### 3.3.3.3 Technological measurements against drought and flood

The floating islands, floating wetlands and devices are always facing flood and dry season. The change of water level and change of water flow can affect their safety. Measures are needed to protect them.

To prevent drought, the system has primary design and temporary measurement. First of all, when the dry season comes, drop of water level could lead to the strand of the original floating island. However, floating island, floating wetlands and purification devices are located in the river by anchor. If water level dropped, anchor can be brought up and the floating island can be moved to a new place with deeper water level. Figure 3.14 shows how anchor devices design and work. The main anchor is used to fix the floating island at usual time, when the drought comes, the vice anchor will be brought up so that the floating island become movable and will be moved into the location with deeper water. What's more, in order to prevent drought season. Plants roots are on purpose located in the river, when dry season comes, the plants can still absorb enough water. Furthermore, even in the extremely dry season, personnel can keep the necessity by artificial watering.

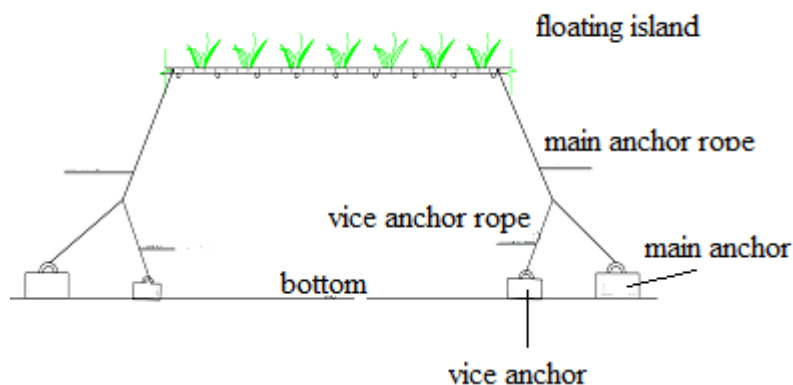


Figure3.14, anchor of floating island, source: Changzhou Environment Protection Science and Technology Development Center

To prevent flood, system also has solution. In the flood period, the floating island and floating wetland face the problem of the raise of water level. Drainage system in Changzhou river system is excellent enough to balance the river level to a normal range within two to three days, so that the raise water will not affect the plants. And even in case the flood covers the plants, because most plants are aquatic or wetland plants, they will be not influenced even under the water for several days.

#### 3.3.3.4 Measurements for safety and stable

There are several measurements to follow for keeping floating islands safe and stable.

1. The movable floating islands ensure floating island can move 2 meters towards center without affecting navigation in dry season, while stuff should bring floating island back to shore in wet season so that water flow will not be blocked.

2. On material use and structure design. Floating islands use high strength material and smooth resistance structure design to reduce the impact of flood and structure damage in previous.

3. Leave space of 10 meters for buffer zone in the water flow impact zone. Do not set the purification facilities and other structures which could impede flood. Instead, build floating wetland and floating island, with appropriate plants on, in order to achieve landscape purpose.

4. Width adjustment of floating island. In dry season, water quality is poor and water flow is small. The floating plants can grow very fast to the center of the river. In wet season when water has good quality and high speed, stuff has to harvest the plants in order to remove nutrients as well as reduce the plants size, so that the floating island will not block the water flow.

5. Floating islands are directly fixed on watercourse, with the help of main anchors and vice anchors, floating islands are ensured to be safe and stable.

6. In the wet season, the project needs to strengthen the management of the floating island safety such as to ensure the fixation of facilities, safety of floating island components, maintenance, repair and reinforcement of floating, etc. Avoid accumulation of floating debris from upstream in control area and also help solve large area hyacinth problem as soon as possible.

7. Under the condition of not affecting navigation, construct interception facilities to collect garbage, trash and broken branches, etc, which may impede water flow and hinder flood.

8. In plant selection, choose strong wind resistance plants to avoid impact and damage from strong winds or heavy rain on floating islands.

#### *3.3.4 Benthic animals*

According to the principles of the ecosystem food chain, in the project our institution stocks filter-feeding animals such as snails, mussels and other benthic animals to achieve production conversion on the one hand, while control the occurrence of water bloom on the other hand, because filter-feeding animals can eat algae, organic debris and dead body which can prevent the water bloom in summer and also black and smell phenomenon in North River, while they are the food of higher level food chain animals at the same time, which create one step of the food chain. In fact, filter-feeding animals pass the energy along the food chain. In one word, raising aquatic living is an important step to maintain the health of aquatic ecosystem.

The selection and stock principle of aquatic animals:

- (1) Do not stock too much of them so that they grow out of control;
- (2) Do not select the kind which causes strong water movement or even affect other water landscape;
- (3) Aquatic animals and aquatic plants will form a reasonable food chain cycle.

### 3.4 Financial statement of the project

In this section, the cost and amount of material of each section of the project are mentioned for readers to see the financial situation and overall investment of the biological restoration of North River, which is 386500 RMB (initial cost for installation and maintenance within the year without operation fee and maintenance fee every other year after).

(1) Substrate modification: sprinkle 1200kg sediment modifier of 0.1kg/m<sup>2</sup> concentration at the southern half of North River. While because northern half of North River has black and odor phenomenon caused by direct or indirect sewage water from residents, the project use mixture of acid hydrogen peroxide and calcium at 0.2kg/m<sup>2</sup> concentration to eliminate the organic pollutant inside sediment.

(2) Biological grids: put 600 m<sup>3</sup> biological grids mainly at southern half of North River. arrange the biofilm suspend under the floating island.

Table of deploy of high level plants (unit: m<sup>2</sup>)

section	Northern half of North River
category	

Floating plants	1200
Standing plants	500
sum	1700

Table 3.3, table of deploy of high level plants, source: Changzhou Environment Protection Science and Technology Development Center

(3) Floating wetland: build 500 m2 floating wetland in northern half of North River with mosaic arundo, donax plant, Siberian iris, force flowers, iris, yellow iris and canna on.

(4) Floating island: build 1200 m2 floating wetland in northern half of North River with coin grass and gather grass on.

(5) Benthic animals stock: stock 800kg benthic animals at southern half of North River at 0.1kg/m2 concentration.

**Table of investment of building biological system in North River**

number	Project and name	COST				
		unit	number	Cost (RMB)	total (RMB)	remarks
<b>I</b>	<b>cost</b>					
1	Sediment modifier	kg	1200	25.0	30000	/
2	mixture of acid hydrogen peroxide and calcium	kg	800	25.0	20000	/
3	Biological grids	M2	600	60.0	36000	/
4	Floating wetland	M2	500	250	125000	Include wetland and plants

5	Floating island	M2	1200	70.0	84000	Include plants
6	Filter-feeding animals	kg	800	12.0	9600	
7	Labor cost	per	400	80	32000	/
I	sum	336600				
II	Maintenance	(I)×5%				16800
III	Design	(I)×6%				20200
IV	tax	(I + II+ III) ×3.448%				12900
V	Total investment	I + II + III+ IIII				386500

Table 3.4, table of project investment source: Changzhou Environment Protection Science and Technology Development Center

**remark: 1. Total investment includes investigation, design and implementation.**

**2. The financial statement is a little different from the practical situation.**

The table 3.4 shows the investment of building biological restoration system in North River. Readers can see clearly the composition of the project and the cost of each section of the project. Sediment modifier per kilogram is 25 RMB costs total 30000 RMB, mixture of acid hydrogen peroxide and calcium per kilogram is 25 kilograms costs total 20000 RMB, biological grids per M2 is 60 RMB costs in sum 36000 RMB, floating wetland per M2 is 350 RMB (including plants) costs 125000 RMB in sum, floating island per M2 is 75 RMB (including plants) costs total 84500 RMB, besides raise of filter-feeding animals needs 9600 RMB, labor cost in the project costs 32000 RMB, maintenance fee within the year covers 16800 RMB, design fee of our institution costs 20200 RMB and finally the tax costs 12900 RMB.

### **3.5 Summary**

This chapter first introduces the situation of North River, before the project, the water quality really needs improvement. Furthermore, the paper describes the process of building biological restoration of North River, including the basic concept of biological restoration, and each step and every component in details: biological grid and oxygen pumping for pre-treatment, sediment degradation to eliminate source pollution, floating island and floating wetland to absorb nourishment and stock of aquatic creatures. At the end of the chapter, the investment of building the project in North River is also given to provide a point of view on financial perspective of the project

## Chapter 4 Data Analysis

After finish the ecological restoration of North River, some questions are raised such as whether the water quality is improved or not by the project, how does the water quality status at different location and at different time within the system and is there anything like weather, season or pollutants affect the water quality? To answer these questions and to better understand the purification function of this artificial biological system, staff from Changzhou Environment Protection Science and Technology Development Center and colleagues from Tsinghua University (the best university in China), cooperated to monitor and analyze the data of water quality status of North River before and after the project.

This chapter uses the data of water quality of North River monitored in different time period - during one day (February 25<sup>th</sup>, 2010), during one week (March 3<sup>st</sup> to April 11<sup>th</sup>, 2010), and during two years from 2008 to 2010 - to analyze the biological system of North River, in order to compare the water condition before and after the project, to see the dynamic process of the change and trends of water quality of North River, to find out influential factors of the water quality, to understand regular pattern of the operation and the meaning of this artificial biological system.

The chapter, first of all, describes the scheme Changzhou Environment Protection Science and Technology Development Center and Tsinghua University used to monitor data of North River water quality, including monitor locations, monitor frequency, monitor methods, and indicators. Then, regular patterns and influencing factors of biological system are analyzed

in several diagrams of different time periods made according to the monitoring data. By doing analysis, the chapter will give us better understanding of the system and even the weakness, problems or space for improvement of the system.

#### **4.1 Monitor Scheme**

The purpose of monitoring water quality status of North River is by regularly monitoring of entering pollutants into the river, to clearly see and understand the dynamic process of the change and trends of water quality of North River, so that the result of "urban river water purification and ecological restoration technology" has scientific demonstration. Colleagues from institution of Changzhou Environment Protection Science and Technology Development Center and Tsinghua University together collected and analyzed the data of water quality. So the conclusion of data analysis has authoritative foundation.

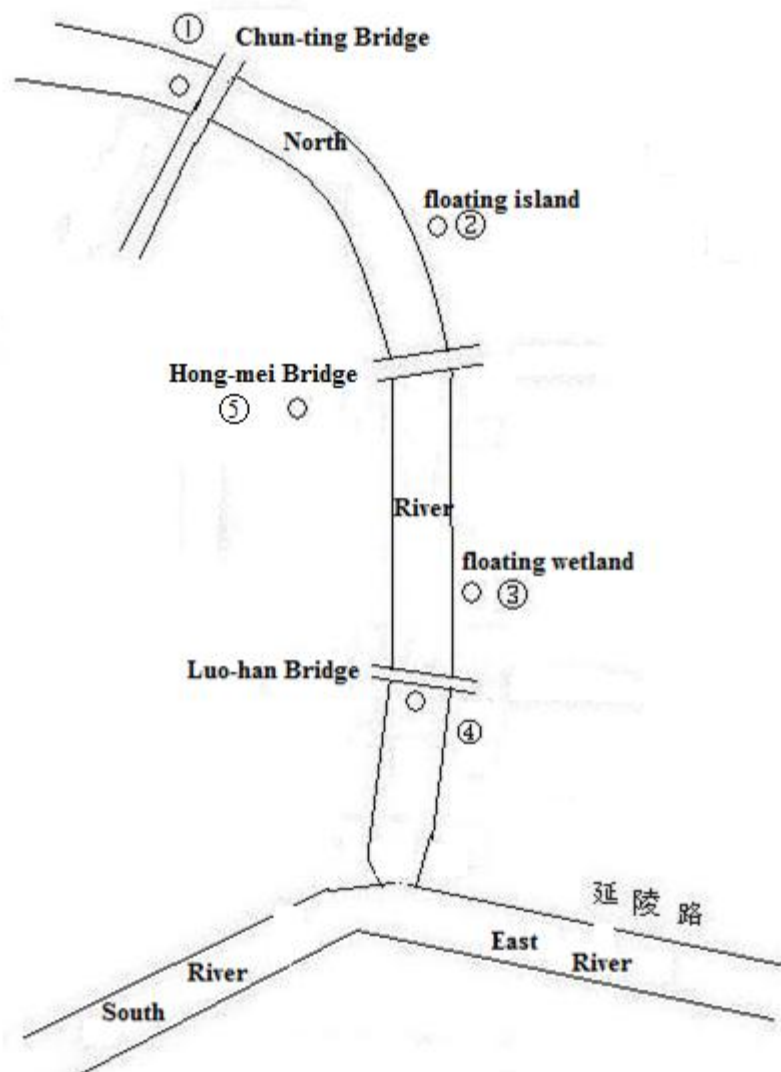


Figure 4.1, monitoring points, source: Changzhou Environmental Protection Science and Technology Development Center

#### 4.1.1 Location

Figure 4.1 shows the overall monitoring situation of North River. North River is from Chun-ting Bridge to Luo-han bridge, has length of the river is about 1500 meters long, with about 2 to 3 meters depth, 16 meters wide, covering about 24,000 square meters area. From Chun-ting Bridge until Hong-mei Bridge is its northern part of the river, which is 500 meters

long, while from Hong-mei Bridge to Luo-han Bridge is southern part of North River, which is 1200 meters. In the biological system, there are five monitoring locations (each of the location is marked in the picture of figure4.1 from number one to number five). The first location is at Chun-ting Bridge which is the beginning of North River. The second one is near one of the floating islands in northern part of North River. Location number three is near floating wetlands that is close to riverbank. It is located at southern part of North River. The fourth one is at Luo-han Bridge which is the junction between North River, East River and South River. The last one, location number five is at Hong-mei Bridge, which is the bridge at the middle of Chun-ting Bridge and Luo-han Bridge.

#### *4.1.2 Monitoring time and frequency*

1. The first data is within two weeks. From March 3<sup>st</sup> to April 11<sup>th</sup>, 2010, at 10 o'clock of every morning, the institution collected data of water quality of North River at monitoring location of number one- Chun-ting Bridge.

2. The second data is within one day. On February 25<sup>th</sup>, 2010, institution measured the water quality at eight different times of that day, including 0 o'clock, 6 o'clock, 8 o'clock, 11 o'clock, 13 o'clock, 16 o'clock, 18 o'clock, 20 o'clock, 22 o'clock, to see the change of water quality during 24 hours of the whole day.

3. Another data has length of two years. Since November 2009, institution detected twice a month at number one monitoring location and number four location sampling point. Except dissolved oxygen layer (50 cm under the surface and 50 cm beyond bottom), other indicators are measured only 50 cm below the surface samples. However, because of working process of our

institution, some of samples from November 2009 to December 2010 are not able to calculate so that in the paper readers cannot see each single data which obey the frequency of twice a month. Besides, the data for North River before 2009 is only monitored once a month at Chun-ting Bridge, so at the analysis, the paper has less data in 2009 than that in 2010. However, the total trend and change of two years' water quality can still been seen clearly in the diagram.

#### *4.1.3 Determination method of sampling points*

Sample set of sample points are based on width and depth of North River. Figure 4.2 shows the cross section map of the river. (1) Set of vertical sampling: According to the width of North River, we set a vertical line in the middle and one side line near the edge. (2) Set of sampling points on the vertical setting: there are three sampling points in middle line, one located in 0.5 m below the water surface, one is 0.5m beyond the river bottom, the third one is in the middle point of the line at the depth of  $1 / 2$  of the river; side line has only one measuring point which is at the 0.5m below surface.

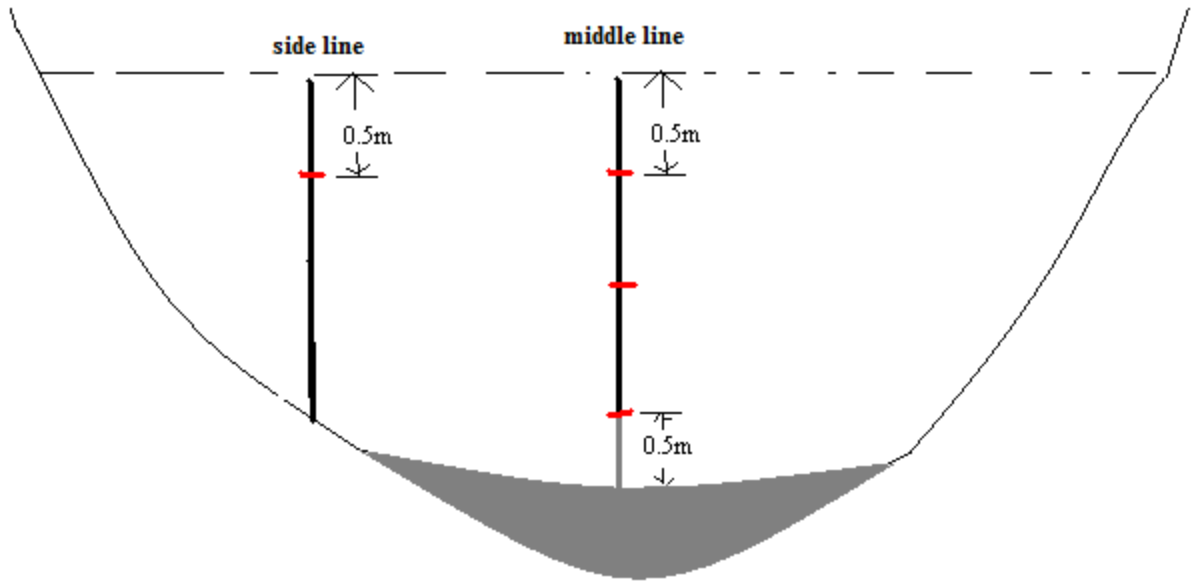


Figure 4.2, Determination method of sample points, source: Changzhou Environmental Protection Science and Technology Development Center

#### 4.1.4 Monitoring indicators

Following indicators are measured in North River by institution: water temperature, turbidity (transparency), pH, dissolved oxygen, CODCr, BOD5, NH<sub>3</sub>-N, total N, total P, dissolved phosphorus, suspended solids, heavy metals (Fe, Mn, Hg, Cd, Pb, Zn, Cu, Cr), chlorophyll, among which, water temperature, turbidity, PH, dissolved oxygen are directly calculated at the field rather than in lab.

indicator	Methods	Reserve time	container	reserve method	
temperature	Temperature method GB 13195-91	——	——	——	Field notes
pH	Glass electrode method GB 6920-86	——	——	——	Field notes
Dissolved oxygen	Electrochemical probe method GB 11913-89	——	——	——	Field notes
Suspended particles	Description (floating membrane, oil class and aggregation of other substances), "Water and wastewater monitoring and analysis methods"	——	——	——	Field notes
Olfactory	Description, "Water and wastewater monitoring and analysis methods"	——	——	——	Field notes
transparency	Cyprus's disk method, "Water and wastewater monitoring and analysis methods"	——	——	——	Field notes
Flow velocity	Doppler flow meter	——	——	——	Field notes
COD <sub>Cr</sub>	Dichromate method GB 11914-89	5d	P or G	Acidification, chilled at 4℃ at dark	
Ammonia	Acid spectrophotometry GB7481-87	As soon as possible	P or G	Acidification, chilled at 2~5℃ at dark	
Nitrogen	Alkaline potassium persulfate digestion spectrophotometry GB11894-89	24h	P or G	Acidification, chilled at 2~5℃ at dark	
Phosphorous	Ammonium molybdate spectrophotometric method GB11893-89		P or G	Acidification, chilled at 2~5℃ at dark	
SS (suspended solid)	Weight method GB 11901-89	7d	P or G	chilled at 2~5℃ at dark	

Table 4.1, measure indicators, source: Changzhou Environmental Protection Science and Technology Development

Center

Note: (1) P is polyethylene bottles, G is glass.

(2) We will measure the Doppler flow velocity meter if we can get the machine.

(3) Filtered suspended solids can be weighted after drying.

#### 4.1.5 Monitoring basis

The process is based on "surface water and wastewater monitoring technical specifications"(HJ / T 91-2002).

#### 4.2 data analysis in 24 hours (on December 25<sup>th</sup>, 2009)

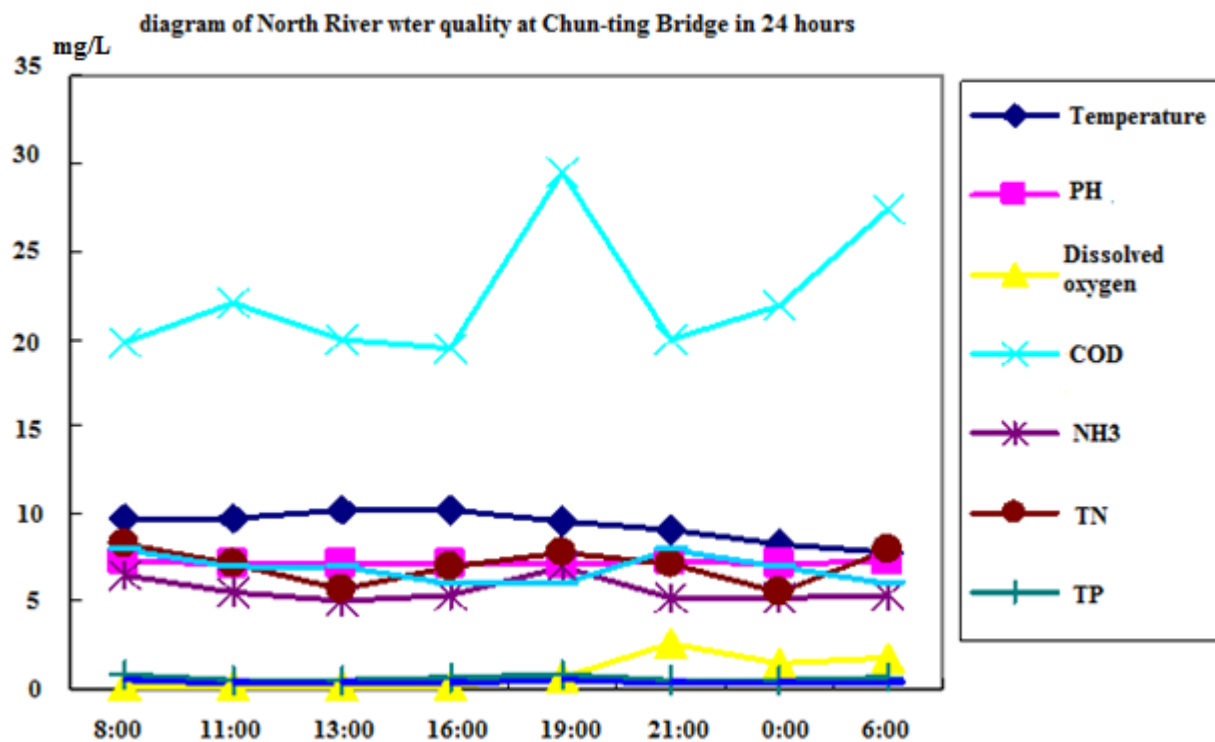


Figure 4.3, data in 24 hours, source: Changzhou Environmental Protection Science and Technology Development Center

This diagram is 24 hours water quality at sampling location of Chun-ting Bridge on December 25<sup>th</sup>, 2009. According to the diagram, we can conclude as follows: (1) Except COD, other indicators have no large diversification during one day. In this diagram, except the light blue curve which represents COD indicator, all of other curves of indicators such as temperature, PH, dissolved oxygen, NH<sub>3</sub>-N, total nitrogen, total phosphorous, are smooth and vary not from 8 o'clock until 6 o'clock, which means these indicators do not change a lot within one day. (2) The total nitrogen and total phosphorous are much higher than the standard of category of V water. Total nitrogen indicator is always higher than 6 while total phosphorous indicator is higher than 0.5, which are worse than category of V water. The explanation would be because at that time-December 25<sup>th</sup>, 2009, the project is just been done, the purification function of ecological system did not work very well and the water quality has not been improved. (3) Dissolved oxygen is very low at the water (lower than 0.5mg/l), however there would be a little more at night time. The yellow curve of dissolved oxygen is keep near y axle and goes a little up around 21 o'clock.

### 4.3 Data analysis of water quality in nine days (from December 3<sup>rd</sup> -11<sup>th</sup>)

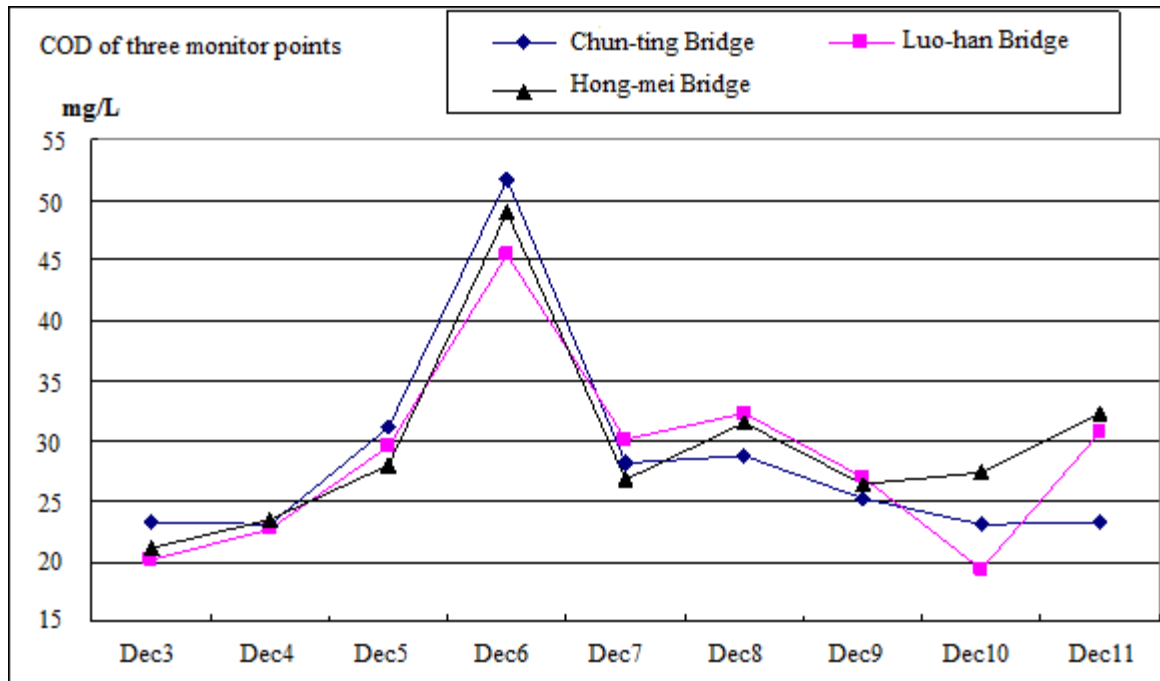


Figure 4.4, COD of three monitor points, source: Changzhou Environmental Protection Science and Technology Development Center

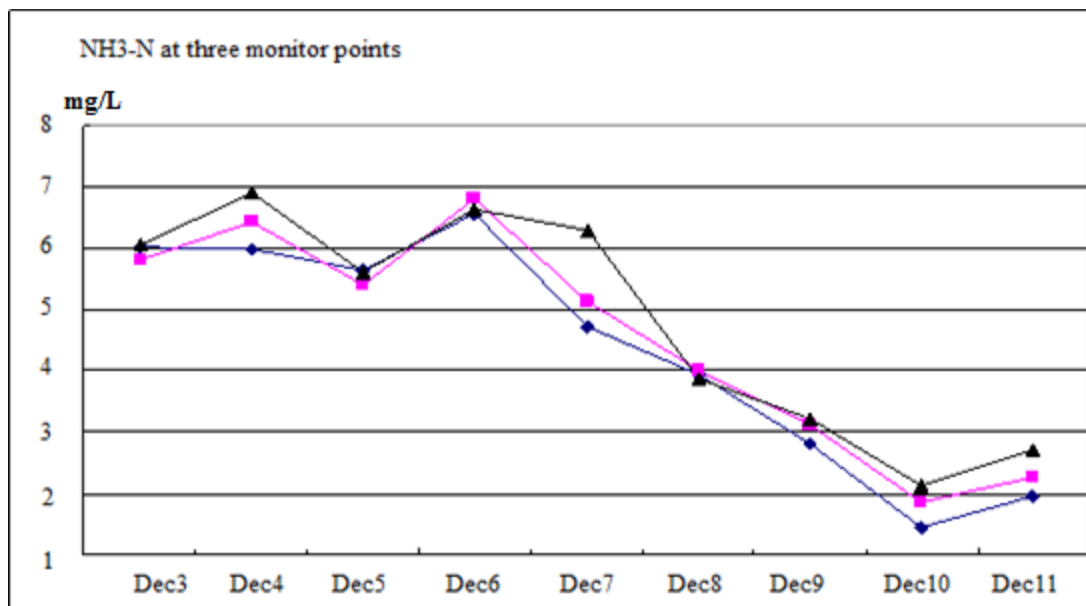


Figure 4.5, NH3-N of three monitor points, source: Changzhou Environmental Protection Science and Technology Development Center

Institution collected data of three bridge sampling points within nine days to see the change and trends of water system in a period. Figure 4.4 is a COD diagram of three sampling points. The data are almost same between three sampling points. The curves increase at first three days, reach their top on December 6<sup>th</sup> and back to the normal level after. December 10<sup>th</sup> seems like their bottom point.

The figure 4.5 is a NH<sub>3</sub>-N diagram of three sampling points. The first four days from December 3<sup>rd</sup> to December 6<sup>th</sup> keeps around 6 and reduces since December 7<sup>th</sup>. On December 10<sup>th</sup> the curves reach their bottom and start to increase again.

According to the diagram, we can conclude that, (1) Along with time, the trends of water quality are almost same to all three points. December 6<sup>th</sup> is highest polluted because the curve reach their top on that day, while December 8<sup>th</sup> and December 9<sup>th</sup> are lightest polluted since that are their bottom points. (2) On the perspective of location, water qualities have no big difference between these three locations, because they have almost same water status according to the data.

The two figures both show that December 6<sup>th</sup> has the worst water quality situation. So is there any possibility that pollution is related to time? The reason of why December 6<sup>th</sup> is the top point the institution assumes is that it is on weekend. To prove the relationship between time and pollution, we compare the water quality in weekend and that in weekday.

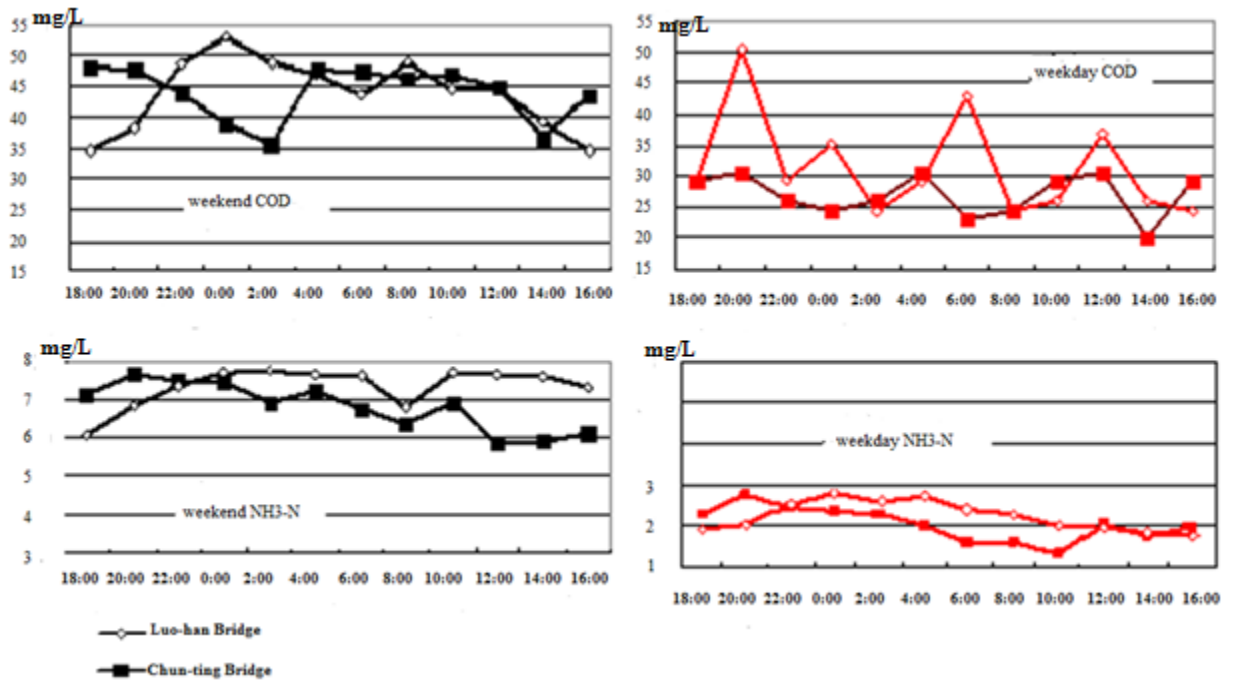


Figure 4.6, water quality compare between weekend and weekday, source: Changzhou Environmental Protection

Science and Technology Development Center

Figure 4.6 is the diagrams of weekend COD, weekday COD, weekend NH3-N and weekday NH3-N of North River. The diagrams in black are weekend data and the diagrams in red are weekday data. To compare the data between weekend and weekday, we can conclude that, COD and NH3-N in weekend are much higher than COD and NH3-N in weekday, which equals that in weekend North River are more polluted than that in weekday. As what the institution assumes at last page, there is relationship between time and pollution. To continue find out the deeper reasons that cause the phenomenon. The paper tries to dig out possible factors during nine days.

These factories are operating as usual in weekend, which means produced pollution discharge amount in weekend are same as that in weekday. So what other factors make

difference? Actually, according to survey, on 8<sup>th</sup> and 9<sup>th</sup>, there is drainage on the up-stream. Water dilution may play a big role on reducing the pollution and improving water quality at that time which is weekday. The dissolved oxygen contain will also increase in the water when the drainage happens, which could eliminate NH<sub>3</sub>-N contain. That could be the reason why weekend pollution is higher than weekday pollution. However with time, the pollution goes back to normal the influence of drainage disappears. The diagrams do not show any regular pattern of pollution in this river. So things we can conclude here is that drainage has impact on improving water quality but the influence does not last long. Water flow in North River has no regular pattern which may cause the water pollution in the water has no regular pattern as well.

What's more, the paper tries to see the relation between pollution source and our phenomenon (weekend is higher polluted than weekday). There are three outfalls at northern part of North River between Chun-ting Bridge and Luo-han Bridge. After analyze the discharge from these three outfalls in weekend and weekday, other explanation of the phenomenon will come out.

Outfall	Q(L)	COD Cr(g)	TP(g)	TN(g)	NH <sub>3</sub> -N(g)
1	23581.01	2431.83	462.79	727.71	45.92
2	95110.56	9898.88	1927.37	2903.67	149.39
3	4806.14	415.99	30.71	57.28	5.95
summary	123497.7	12746.7	2420.87	3688.66	201.26

Data of outfall discharge of North River in weekend

Outfall	Q(L)	COD Cr(g)	TP(g)	TN(g)	NH3-N(g)
1	27642.38	2611.75	713.42	1315.86	84.91
2	85395.17	5198.31	1033.07	2829.97	163.43
3	4206.67	220.45	34.72	124.16	7.48
summary	11724.42	8030.51	1781.21	4269.99	255.82

Data of outfall discharge of North River in weekday

Table 4.2, data compare of outfall discharge between weekend and weekday, source: Changzhou Environmental Protection Science and Technology Development Center

After compare, we can see several conclusions from the two tables, that (1) number 2 outfall pollutes most among three outfalls, it discharges much more, no matter Q, COD, TP, TN, NH3-H, than the other two. (2) The contribution of pollution on the river from high to low is COD, TN, TP and NH3-N. (3) On the perspective of time, water quality in weekend is worse than that in weekday, especially the indicator of NH3-N. However, water quality has positive correlation with amount of COD discharge rather than amount of NH3-N discharge.

In one word, water drainage and pollution discharge both affect water quality of North River. And there is no big difference of water status at any location of North River.

#### 4.4 data analysis of water quality from 2009 to 2010

After see the regular pattern and polluting factors of North River, we start to see biological system and its impact on North River. In this section, paper try to compare the data of NH<sub>3</sub>-N, TN, TP between 2009 and 2010, so that we can clearly see the purification function of the biological system and phenomenon of largely pollution decrease.

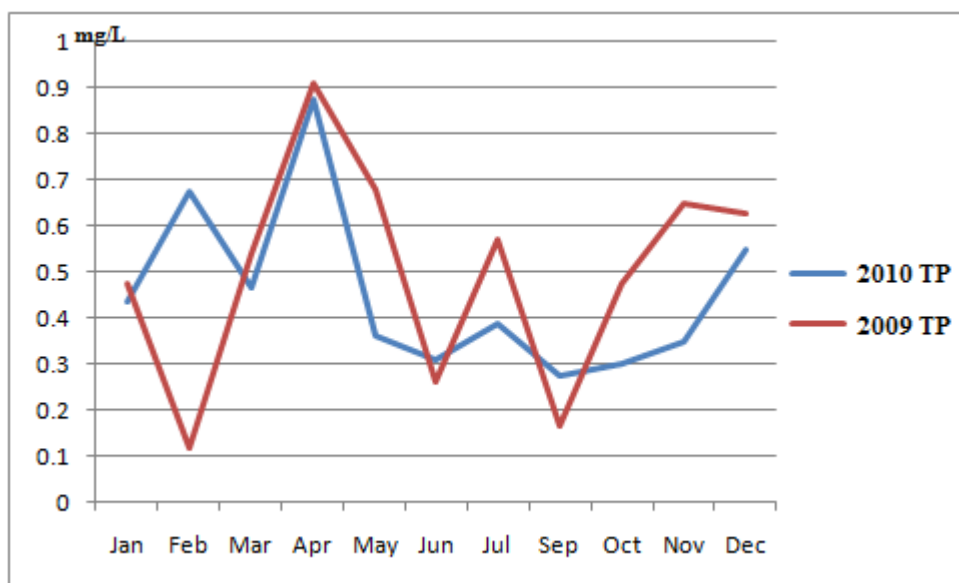


Figure 4.7, TP of 2009 and 2010, source: Changzhou Environmental Protection Science and Technology Development Center

Figure 4.7 is a diagram of total phosphorous situation compare between 2009 and 2010. The red line is 2009, blue line is 2010. According to diagram, except February, at most of time, TP in 2009 is higher than that in 2010 and TP in 2010 is more stable than 2009, which means the system functions stable and control TP in North River.

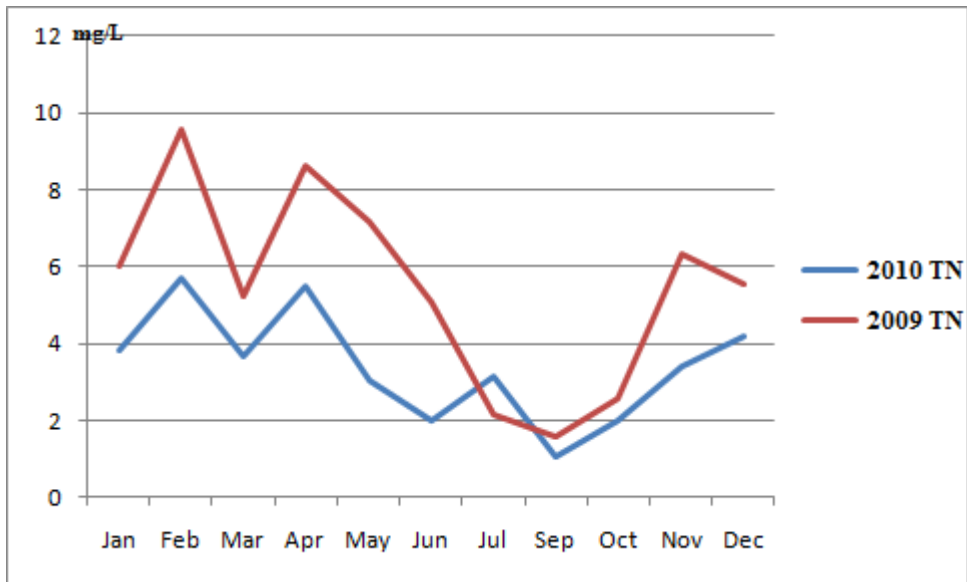


Figure 4.8, TN of 2009 and 2010, source: Changzhou Environmental Protection Science and Technology Development Center

Figure 4.8 is a diagram of TN compare between 2009 and 2010. Red line is 2009, blue line is 2010. The curves on diagram clearly show the indicator TN in 2010 is much better than that in 2009. Also the TN in 2010 is much more stable than that in 2009. We can conclude that after the project, TN of North River is largely reduced in 2010.

From these two diagrams, we can see the biological system actually achieve pollution reduction and water quality control.

#### 4.5 Data analysis of water quality (twice a month) from November 24<sup>th</sup> to November 24<sup>th</sup>

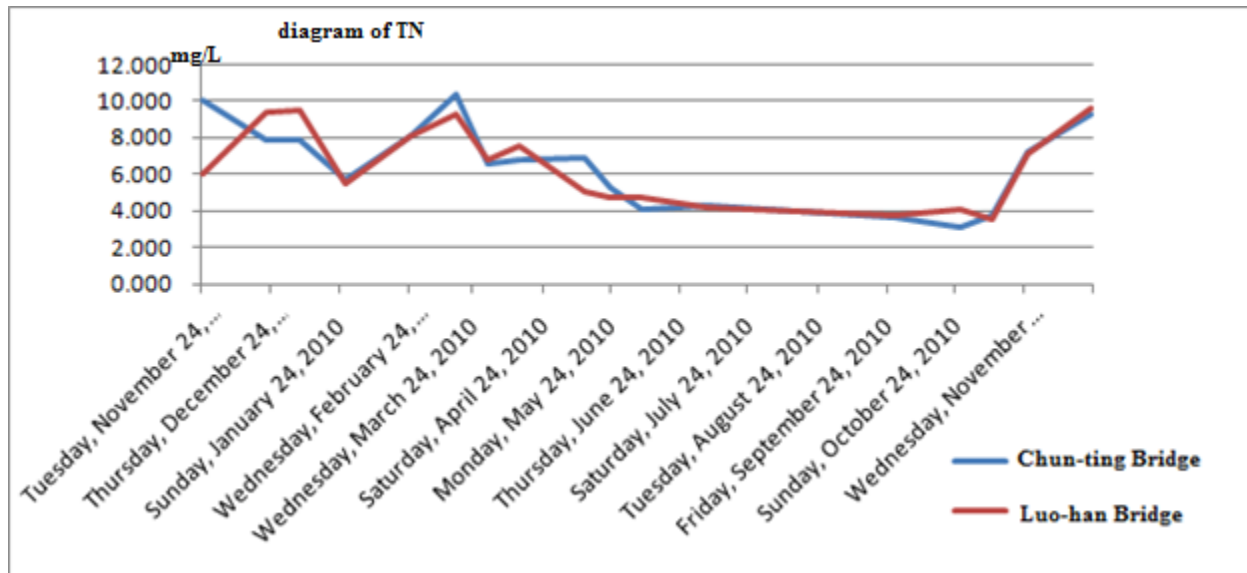


Figure 4.9, TN curves, source: Changzhou Environmental Protection Science and Technology Development Center

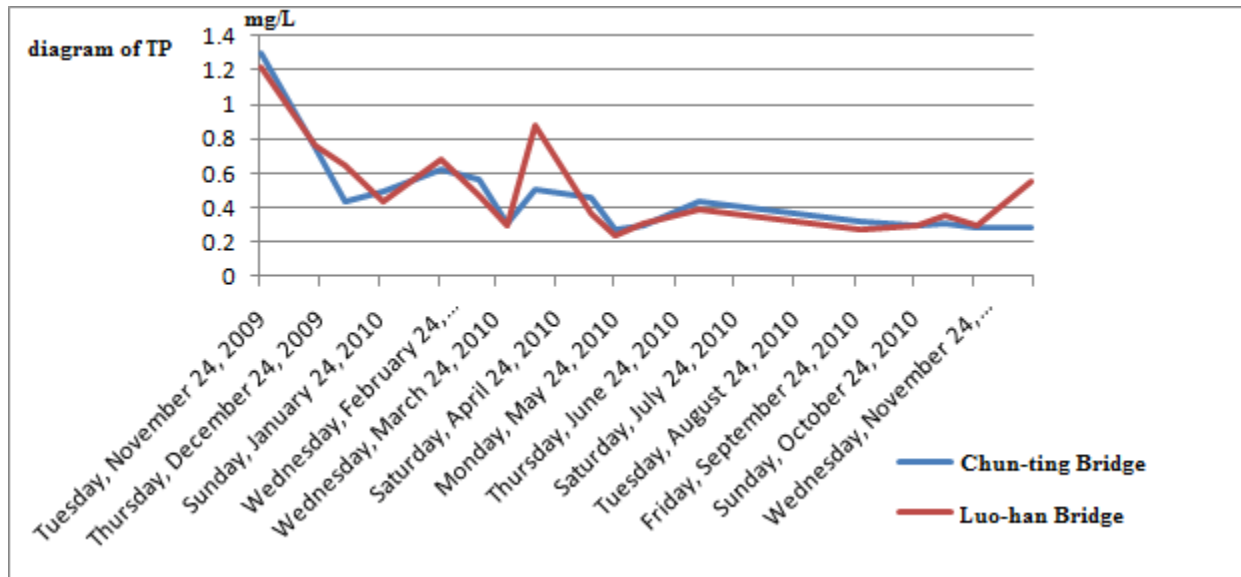


Figure 4.10, TP curves, source: Changzhou Environmental Protection Science and Technology Development Center

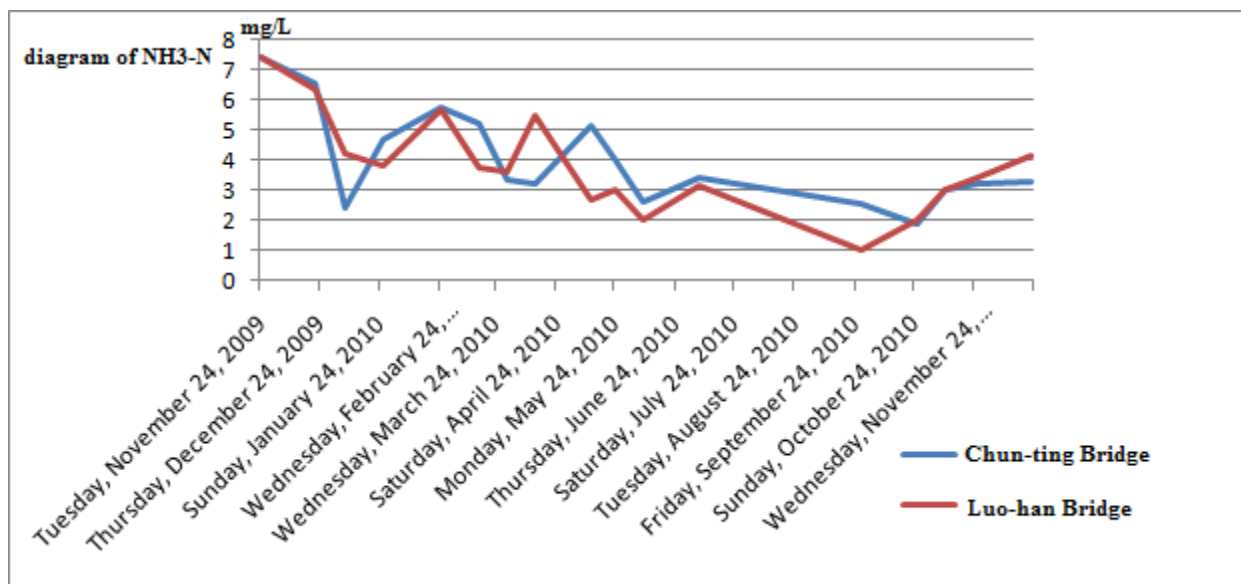


Figure 4.11, NH<sub>3</sub>-N curves, source: Changzhou Environmental Protection Science and Technology Development Center

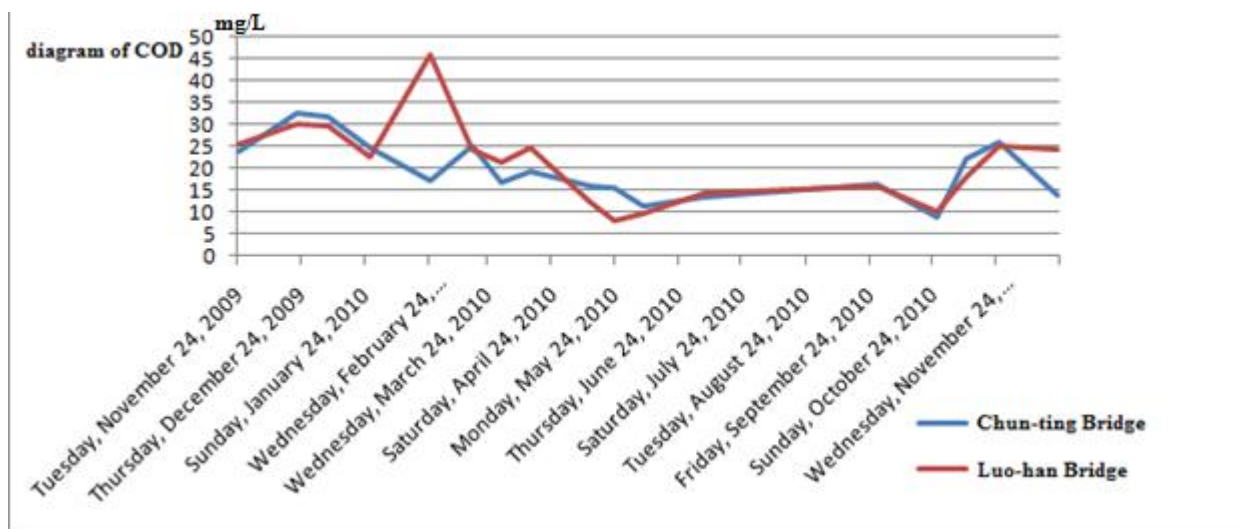


Figure 4.12, COD curves, source: Changzhou Environmental Protection Science and Technology Development Center

Figure 4.9, figure 4.10, figure 4.11, figure 4.12 are the diagrams of indicators of TN, TP, NH<sub>3</sub>-N, COD at sampling points of Chun-ting Bridge and Luo-han Bridge from November 24<sup>th</sup> 2009 to November 24<sup>th</sup> 2010. The data is collected twice a month with some data missing due to that some data have not been able to calculate on certain days. Blue curves are data at Chun-ting Bridge and red curves are data at Luo-han Bridge.

The changes and trends of two curves are almost same in these four diagrams, which means, that water quality statuses at two places are similar. As mentioned in section 3.2, the water flow of North River has no regular pattern which means there is no difference of purification level of system at point of Chun-ting Bridge point and at point of Luo-han Bridge.

In all of the diagrams, curves of indicators are at the top at the very beginning and start to reduce. When they reach April 24<sup>th</sup>, 2010 or some point, the pollution level keeps low and stable. However the curves go up again after October 24<sup>th</sup>, 2010. To explain the diagrams, we use biological system functionality and natural pattern. The restoration project of North River finishes in around November 2009, that's the reason why pollution levels are very high, the curves start at the top position. With the function of the system, the pollution starts to reduce, water quality of North River start to improve according to diagram. Since November 2010, both curves go up again, which means the biological system loses its purification function after October.

We assume that the weather and temperature during February until October fit the function of biological system. After compare the growth circles of spinach, water peanuts, mosaic bamboo reed, wild rice stem, cattail, iris, yellow iris, and canna institution used on floating islands and floating wetlands, we find out that most of them are functioning in spring and summer. So it is reasonable that at autumn and winter the pollutants such as nitrogen, phosphorous are not able to be eliminated from water very well. Diagrams in this section give us a conclusion that our biological system has a function period.

#### **4.6 Space for improvement**

Because the biological system has function period, as we mentioned in section 3.5, the system faces some problems. First of all, purification capability of North River becomes very low in autumn and winter so that degraded water quality brings back the black and smell phenomenon. Furthermore, the pollutants collected inside the river could kill the living creatures and raise another vice circle we mentioned in section 3.2.1. Excess oxygen is consumed leads to dead body, organic debris and suspended particles which in turn destroy the standing plants and floating plants of our biological system. What's more, dead plants of our system could cause more anaerobic respiration and water pollution.

It is reasonable to repair the system every year, if the biological system faces the problems. In that case, our institution put more investment into the river every year, new plants are planted, new chemical mixture are sprayed, new benthic animals are raised and more important, the biological system is not sustainable on the perspective of material flow

management, due to it does not achieve the situation in section 1.2.2. The process is not optimized and large amount of unnecessary money is waste every year. The solution should be making the system more sustainable.

To achieve sustainable restoration and economic operation, continuity is a key to connect function period and next year's function period. Winter plants such as ryegrass (ryegrass is a kind of plant that functioning in cold weather) can be added into the system to keep the purification capability of biological system in autumn and winter. By adding winter plants, the system purification function can keep stable and river water pollution level as well. Then the investment for rebuild and repair of the system will be saved, in turn creates a more sustainable system.

Meanwhile, traditional method of river purification is still important. Pollution sources such as industrial discharge and residential waste water, dust along with rainwater should be reduced and controlled.

#### **4.7 summary of data analysis**

By analyze the diagrams of water quality in North River within one day, within nine days, within two years based on data collected in a scientific method by Changzhou Environment Science and Technology Development Center and Tsinghua University. We have a better understanding of North River and our biological system and be able to answer the question

mentioned at very beginning of this chapter: whether the water quality is improved or not by the project, how does the water quality status at different location and at different time within the system and is there anything like weather, season or pollutants affect the water quality?

First of all, formal sections of diagrams are describing water patten of North River. On the perspective of location, there is no big difference of water quality status in North River due to its no regular pollution patten results from not regular water flow pattern. On the perspective of time, pollutants indicators are almost same within 24 hours. In the first section diagram, except COD, every other indicator has no large diversification. The factors that affect water quality in North River are as follows: water drainage, pollution source, seasons. At meantime indicator of COD is directly correlated to water pollution level.

What's more, purification function of biological system is also analyzed in later diagrams. According to diagrams of water quality compare between 2009 and 2010, it is obvious that water quality is improved by our system. Furthermore, our biological system has its working period. The main function time is in spring and summer. In autumn and winter, the water pollution problem may come back. Plants rotation could be a solution that add winter plants into the whole system to achieve longer system function period and also more economic and sustainable system operation.

## **Chapter 5 selection of plants for absorption of nitrogen and phosphorus**

On the perspective of MFM, optimization is always possible and necessary. After the establishment of the system, we try to study the possibility of system improvement in order to implement the MFM.

By observation, the plant is the key point of purification function of our biological system. The absorption efficiency of these standing plants and floating plants determines the system's efficiency of absorption of nitrogen and phosphorus. One of the methods to optimize the process is to increase the system efficiency which equals to selection of the plants with highest absorption efficiency.

On this chapter, different plants (hydroponic Canna, bowl planted Canna, Yellow Iris, Red Water, lily, coin grass), usually used in the biological system, are experimented and compared here to figure out which has the most efficiency and is best for purification.

### **5.1 experiment methods**

Foam board with size of 45cm×30cm×2cm is used as floating island carrier, size of hole and space between holes are made according to characteristics of plants. Before plant, roots are covered by sponge. Then foam board is put inside water box with same size (50cm×30cm×2cm). One box only contains one single species.

The experiment is implemented in the lab of Changzhou Environment Protection Science and Technology Development Center. Water is from one certain urban river in Changzhou. Each box contains 30L water with depth of 20cm, the experiment is made through the period from June to August of 2008. The lab temperate is kept in 23 degrees. There are always abundant sunlight and ventilation in the lab. Distilled water is added into the box to compensate the water evaporation.

Primary water condition is as follows:

Project analysis (average)	Standard value ( level V )	Sample water (average)	
Standard of Chemical demand	$\leq 40$	49.32	exceed
Nitrogen	$\leq 2.0$	10.02	exceed
Phosphorus	$\leq 0.4$	1.02	exceed
NH3-N	$\leq 2.0$	5.91	exceed

Table 5.1, water quality of sample water, source: Changzhou Environment Protection Science and Technology Development Center

In the experiment, we use plants or flowers which are often used in floating islands and floating wetlands, as follows: hydroponic Canna, bowl planted Canna, Yellow Iris, Red Water, lily, coin grass. Ones that grow well, with no pest and no facilities during vegetation are selected in the experiment. Sample water is the only source of nutrient during the experiment. Every 24 days, 100ml water is taken to monitor the TN, TP, NH3-N, COD of the water. TN is measured by alkaline digestion overcurrent Determination of potassium, TP copper ammonium

spectrophotometric determinate (according to GB11893-89), COD by dichromate method (according to GB11893-89).<sup>12</sup> There is also a compare box which has no plants inside. So the data of water quality in 24 days, 48 days and 72 days are collected.

## 5.2 results and discussion

	TN				TP				NH <sub>4</sub> <sup>+</sup> -N				COD <sub>cr</sub>			
Purification time	0	24	48	72	0	24	48	72	0	24	48	72	0	24	48	72
Initial content (mg/L)	10.02				1.02				5.91				49.32			
Hydroponics Canna (mg/L)		0.74								0.53				27.29	17.35	21.17
Bowl planted Canna (mg/L)		7.58	3.47	1.29		1.22	1.06	0.98		5.76	0.55			34.40	29.67	20.70
Yellow Iris (mg/L)		3.23								1.28				38.50	23.23	23.02
Red water lily (mg/L)		6.14	2.56	0.93		0.83	0.62	0.50		4.59	1.59			36.13	21.96	21.64
Coin grass (mg/L)		7.62	3.72	1.04		0.89	0.65	0.53		5.33	0.48			38.50	22.88	22.84

<sup>12</sup> State Environment Protection Administration; Water and Wastewater Monitoring and Analysis methods; the fourth edition, Beijing; China Environment Science Press; 2002

Compare (no plant) (mg/L)		8.55	7.81	7.62		0.85	0.90	0.91		4.90	5.15			42.22	48.25	47.23

Table 5.2, absorption data of different plants, source: Changzhou Environment Protection Science and Technology Development Center

The table provided by Changzhou Environment Protection Science and Technology shows the water quality of different boxes in 24 days, 48 days and 72 days. Absorption efficiencies of different plants are reflected by the data of water quality of different boxes. Less polluted water in the box means that the specific plant has better absorption ability. There is no data of TP absorption of Hydroponics Canna and Yellow Iris, because the two plants do not good at TP absorption. And the data of TN absorption and NH<sub>3</sub>-N absorption of Hydroponics Canna and Yellow Iris in 48days and in 72days are also missing, because the TN and NH<sub>3</sub>-N contain became almost zero when it comes to 48 days and 72 days.

According to the table, diagrams are made to compare the TN, NH<sub>3</sub>-N, TP, COD elimination efficiencies of different plants as follows.

### 5.2.1 TN absorption efficiency

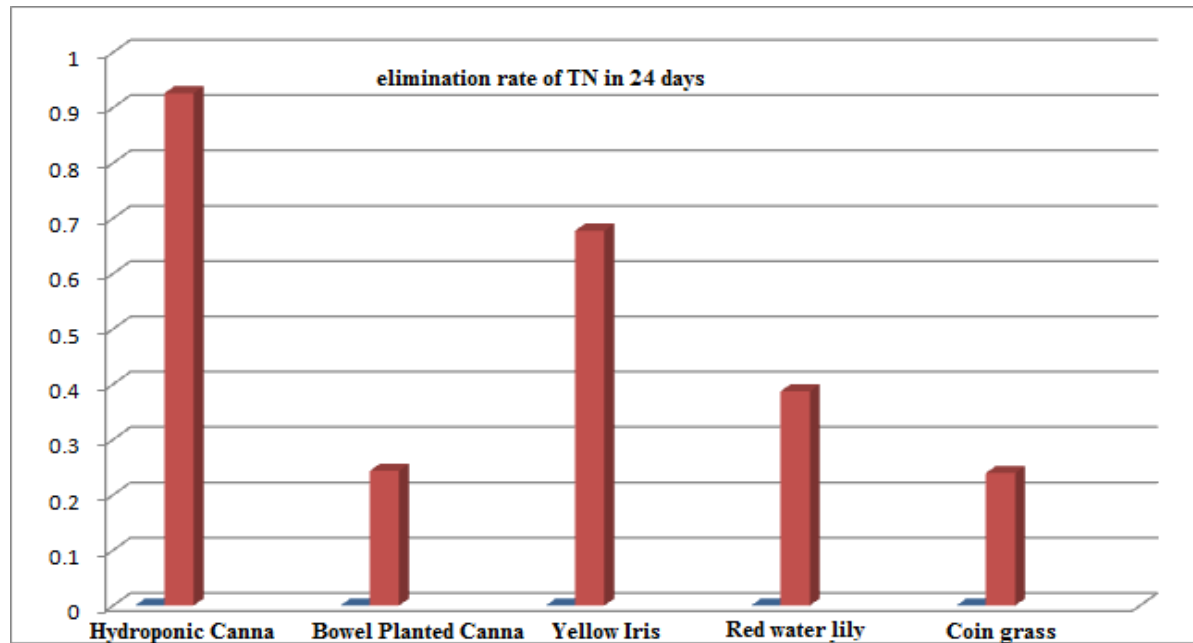


Figure 5.1, compare of TN elimination in 24 day, source: ZHANG Zhongyao, IMAT Ritsumeikan Asia Pacific

Diagram 5.1 shows the TN absorption in 24 day, the TN elimination of Hydroponics Canna, Bowel planted canna, Yellow Iris, Red Water lily and Coin grass are 91%, 24%, 68%, 39% and 24%. In 24days, Hydroponic Canna has the highest absorption elimination rate of TN.

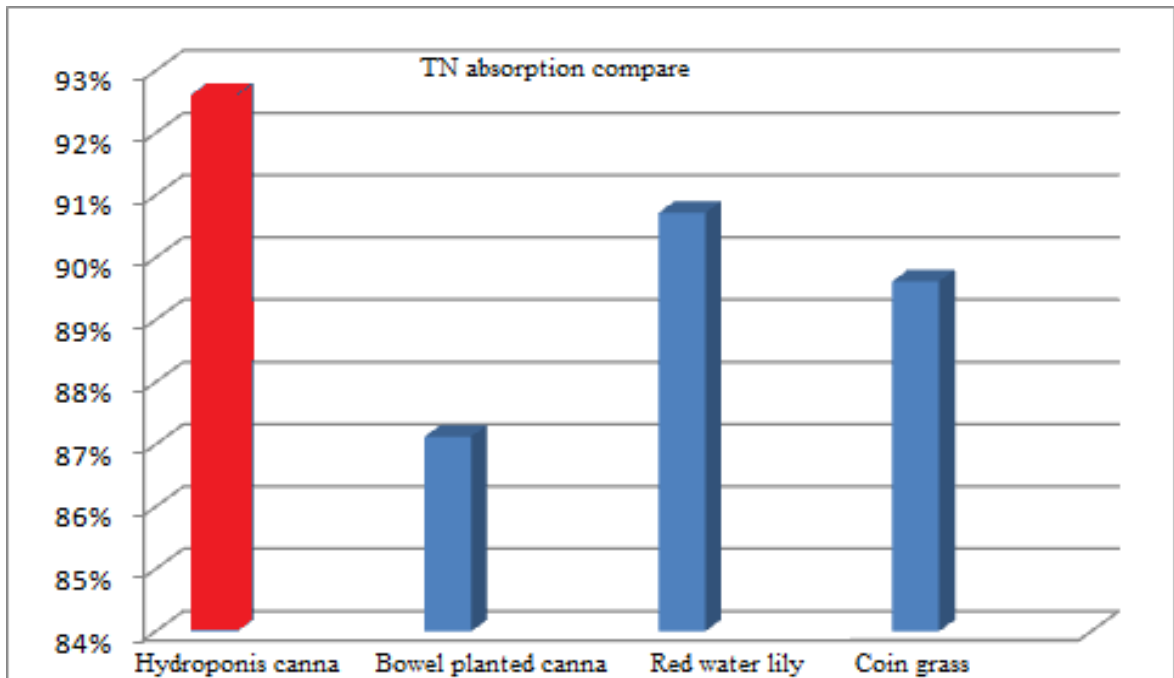


Figure 5.2, TN absorption compare, source: ZHANG Zhongyao, IMAT Ritsumeikan Asia Pacific

In diagram 5.2, TN absorption rate in 72 day are compared here. Bowel planted canna, Red water lily and Coin grass have TN efficienies of 87%, 91% and 90%. The red column is TN absorption of Hydroponis canna in 24 day, is still the highest data among these rates. In a word, Hydroponis canna has the highest TN absorption efficiency. While Bowel planted canna has the lowest TN absorption efficiency.

### 5.2.2 $\text{NH}_3\text{-N}$ absorption efficiency

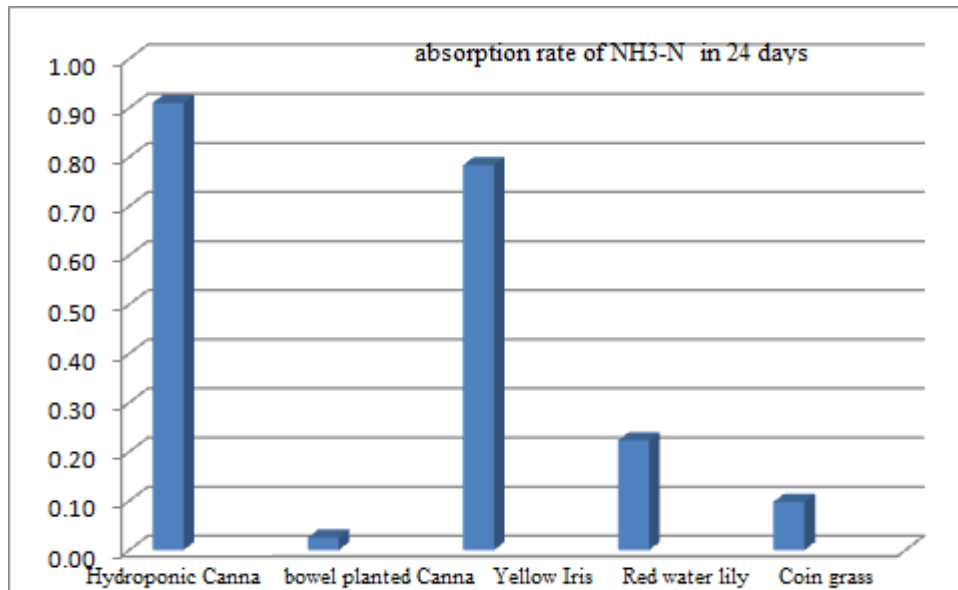


Figure 5.3,  $\text{NH}_3\text{-N}$  absorption compare in 24 day, source: ZHANG Zhongyao, IMAT Ritsumeikan Asia Pacific

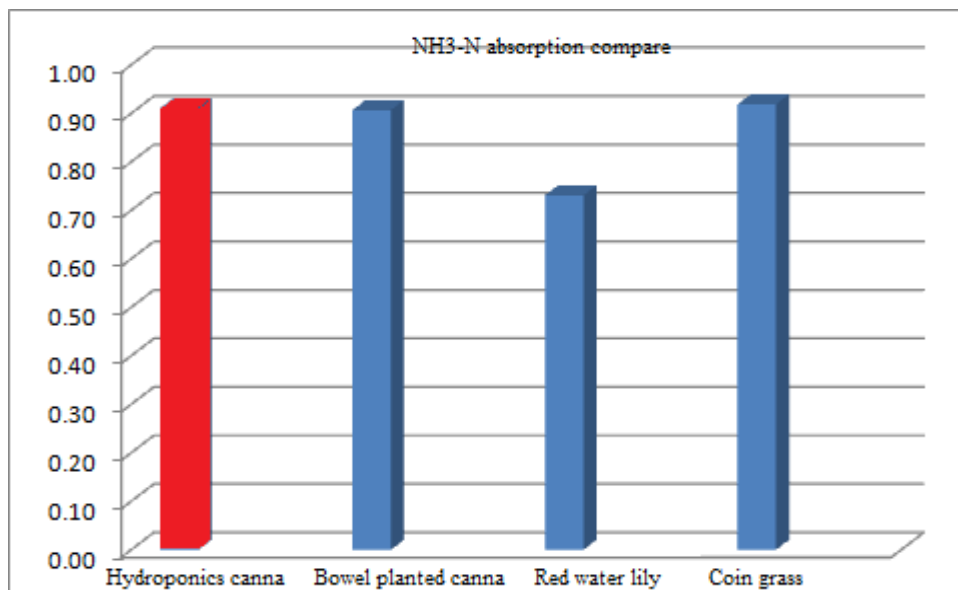


Figure 5.4,  $\text{NH}_3\text{-N}$  absorption compare, source: ZHANG Zhongyao, IMAT Ritsumeikan Asia Pacific

Diagram 5.3 and diagram 5.4 show the compare between  $\text{NH}_3\text{-N}$  absorption efficiencies of these different plants. Hydroponics canna has efficiency of 91% in 24 day. Bowel planted canna has 3% in 24 day and 91% in 48 day, Yellow Iris 78% in 24 day, Red water lily 22% in 24 day and 73% in 48 day, Coin grass 10% in 24 day and 92% in 48. According to the diagrams, it is obvious that Hydroponics canna has the highest absorption rate of  $\text{NH}_3\text{-N}$ , while Bowel planted canna has the lowest  $\text{NH}_3\text{-N}$  absorption efficiency.

### 5.2.3 TP elimination efficiency

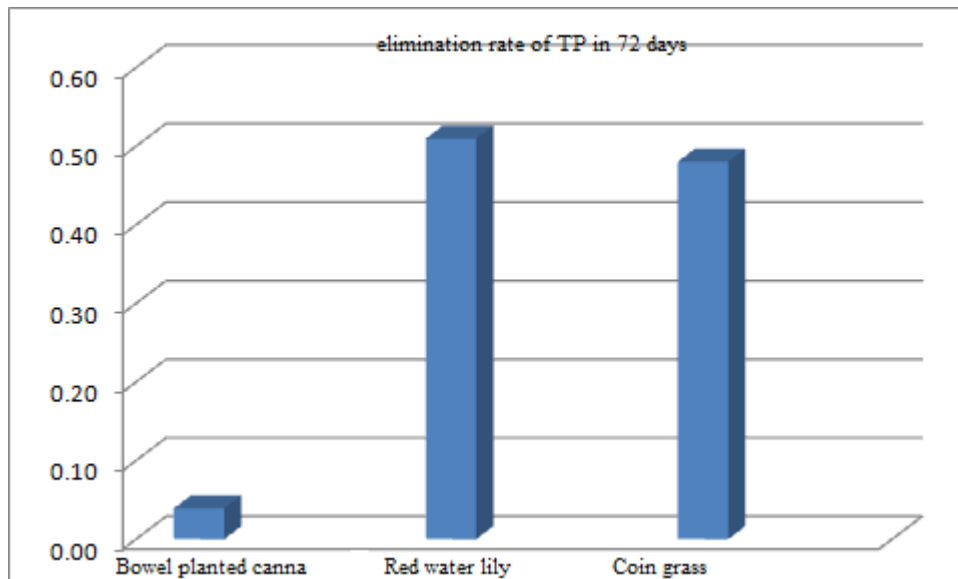


Figure 5.5, TP elimination in 72 day, source: ZHANG Zhongyao, IMAT Ritsumeikan Asia Pacific

The diagram 5.5 shows the TP absorption rate of different plants in 72 days. After compare the TP absorption rates of different plants, we can see that Red water lily has advantage

in TP elimination, 51% is higher than 4% Bowel planted canna and 48% Coin grass 48%. Bowel planted canna has the lowest TP absorption efficiency.

#### 5.2.4 COD elimination efficiency

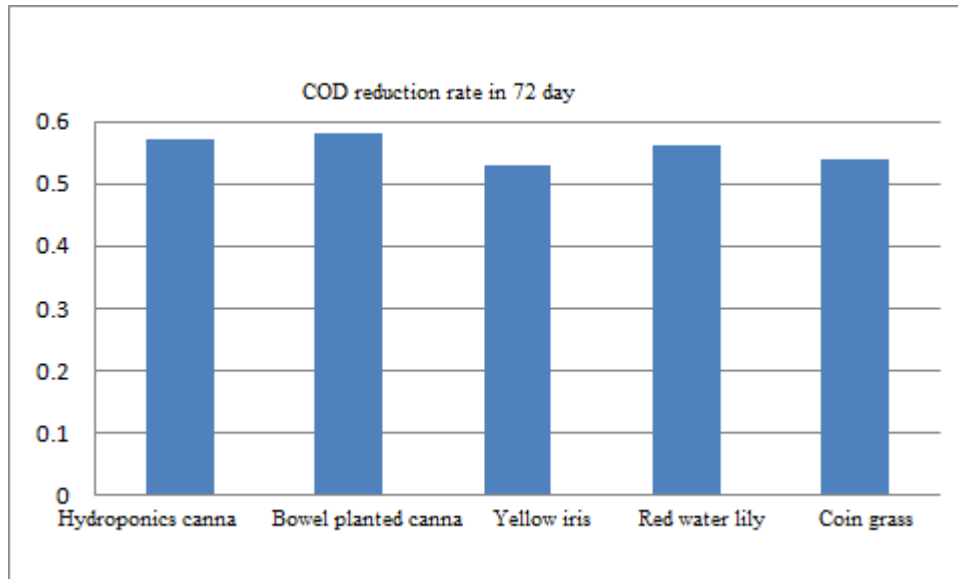


Figure 5.6, COD elimination in 72 day, source: ZHANG Zhongyao, IMAT Ritsumeikan Asia Pacific

Among COD elimination efficiencies of Hydroponics cann (57%), Bowel planted canna (58%), yellow iris (53%), Red water lily (56%) and Coin grass (54%), Bowel planted canna has the highest elimination rate. However, diversification between of these plants in COD elimination rate is very small. The rate is ranged from 53% to 58%.

### *5.2.5 Summary*

After compare, we can understand better of purification efficiency of each plant. Readers can see that Hydroponics canna has the highest elimination efficiency in almost every aspect. In aspect of TP, Red water lily has the highest absorption rate. Bowel planted Canna has the lowest absorption efficiency in almost every aspect. All these plants are used in our system currently, however some has higher efficiency and some has lower. On the purpose of optimize the system, plant in higher absorption efficiency should be chosen in the plant selection to increase the whole system efficiency. So, we recommend that in the later project, Bowel planted canna are suggested not to use anymore and replaced by more hydroponics canna and Red water lily, after which our biological system can achieve optimization and total efficiency increase.

On the further research, investigation could be focused on living conditions for the working of the plants. How other living creatures within the system (such as algae, benthic animals and fishes) affect the absorption efficiencies of the plants. Which plants and creatures could be the best combination for river purification.

## **Chapter 6 Conclusion**

The paper tries to build an overall picture of the biological restoration of urban rivers. It takes Changzhou North River as case study, describing the “urban river clarification” project, the process of building an artificial biological system in North River in details and data analysis of water quality which reflects the regular pattern of the river and also the purification function of North River. Author also gives suggestion for optimization of the biological system.

First of all, basic introduction is made of Changzhou urban river clarification project. Background, meaning and benefits of the project, process of the project and also how does it look like on the perspective of MFM. What’s more, the next chapter describes in details every single step and component of the biological restoration and also the practical financial investment situation of building the system in North River. Data analysis of water quality monitoring of one day, nine days and two years are made to shows the process of change and trend of North River and also the operation of the system. Consideration of system improvement is also thought in the section. After compare of absorption efficiencies of plants that usually used in project, Hydroponics canna and Red water lily are suggested to be used more often due to their high efficiencies of absorption rate.

Actually, in furthermore research, compare experiment of absorption efficiency can be made to include some plants that work well in winter season, so that suggestion of which winter plants can be selected for rotation is able to make. And also the investigation could be made on

biodiversity and coexistence between the favored plants for purification on the one hand and living creatures such algae, fish, benthic animals on the other side.

Biological restoration is a great method compare to traditional ones, as we described in the whole paper, more sustainable, with added value and combined of economic, environment and society. More and more cities in China are going to build their own biological restoration system to cure their river problems. In the future, the system will become more stable, coherent and optimized with plants rotation, better absorption plants and living conditions. The investment of the project will also be cheaper with the proper design.

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