Journal of Environmental Sciences Vol.17, No.1, pp.62—66, 2005 ISSN 1001—0742 CN11—2629/X

Article ID: 1001-0742(2005)01-0062-05 **CLC number**: X171 **Document code**: A

Designing principles of an ecological water storage basin on coastal saline: a case study

LIU Ping-ping[1], YIN Cheng-qing[1,*], QU Jiu-hui[1], ZHANG Guang-yun[2], FENG Wen-qing[2], LIU Jun-xin[1], ZHONG Zhi[2]

(1. SKLEAC, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China. E-mail: cqyin@mail.rcees.ac.cn; 2. TEDA Waterworks Co., Tianjin 300457, China)

Abstract: The degradation of water source environment becomes serious problems accompanying with rapid urbanization in China. Ecological engineering provides ecologically sound and cost-effective solution to solving this problem. As a case study, a 15 hm^2 ecological water storage basin for a water plant was designed and constructed on the TEDA area in Tianjin City. Located on saline, the construction of this project has to face serious difficulties, such as high salinity, scarce seed banks of macrophytes, and strong winds. Freshwater replacement, soil amendation and macrophytes planting at the basinshore, wooden water breaker and plastic membrane installation and other measures were conducted for the assistance of plant community establishment. The result showed that the chloride concentration in the basin water decreased from 11600 mg/L to less than 100 mg/L, and the chloride content in the basin sediment decreased from 2.1% to 0.35% after freshwater soaking. The introduced macrophytes of 8 species all survived and 11 other macrophytes species were occurred in the basin. A new ecosystem was created with increased biological diversity in the original saline, and the water quality was improved. This ecological water storage basin also provided a pleasing landscape for local people.

Keywords: drinking water source; water quality; coastal saline; urban; ecological engineering

Introduction

The water source environment were seriously degraded accompanying the rapid urbanization in China. The drinking water quality is generally low in China. About 46.5 percentage of rivers have been polluted, and those rivers across the urban areas account for 90% (Xiao, 2001). Organics and NH_4^+ are the main pollutants in water sources, and they are difficult to remove by the traditional water treatment system. Unavoidably, some contaminated water may have to be used as the source for drinking water due to increasingly scarce new water sources and the demand of growing populations. Therefore, it is increasingly stringent for providing more amounts of drinking water with new pretreatment technologies in the process of urbanization.

Ecological engineering offer the ecologically sound and cost-effective method to improve water quality (Breaux, 1994; Kadlec, 1996; Zhang, 2000; Mitsch, 2000). Ecological engineering is "the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both" (Mitsch, 1996; 1998). The use of wetlands can lead to dramatic improvements in water quality with the processes of filtration, adsorption, absorption, and assimilation. Furthermore, these wetlands may become scarce landscape entities. The wetlands in urban areas have additional benefits for both human and nature, such as stormwater and flood control, habitat for wildlifes, and recreational, educational and aesthetic values (Zedler, 1990; Simenstad, 1996; Casagrande, 1997; Rybczyk, 1995). This paper describes the design principles and construction of an ecological water basin on coastal saline in an urban area, and focuses on solving many problems, such as high soil salinity. This ecologically civil project provided an approach to integrate ecological construction and economic development in new urban area in China.

1 Study site

Tianjin Economic-Technological Development Area (TEDA) with the area 33 km^2 is one of the biggest coastal development areas in China. Because the existing water basin in the TEDA Water Factory, with the volume of 1.5×10^5 m^3, can not meet the increasing demand of water supply, a new water basin, with the volume of 5.0×10^5 m^3, was planned in 2000, to store the freshwater from Yuqiao Reservoir. It was planed that the basin was located as the part of the TEDA Forest Park, a 30 hm^2 area, which was initiated for attracting international investment.

TEDA is lying in the western coast of the Bohai Sea. Being as a saltern before establishment, its 1 m topsoil has a high salt content, 4%—7%. The soil organic matter content is among 1.02%—1.41%. The mean annual temperature is about 12℃. Mean annual precipitation is 622 mm while evaporation amount is 1931 mm.

2 Design scheme of the ecological water storage basin

Through evaluation of construction goal, the water basin was designed as an urban wetland with the diversity freshwater species. The implementation scheme of this concept in 2001 is proposed in Fig.1. Freshwater is not only an economic resource but also a landscape resource in TEDA, since this city was established on coastal saline. This created water basin has the functions: (1) as water storage for water plant; (2) as a water quality improvement reactor

Foundation item: The Chinese Academy of Sciences (No. KZCX1-SW-12), and the National Hi-Tech R&D Program (863) of China (No. 2002AA601011-05);
* Corresponding author

through natural ecological processes; and (3) as an aesthetically pleasing landscape for the local people. Subsequently, it was emphasized that its ecological properties developed with its own natural processes to perform ecosystem functions, which differ from the traditional water basin engineering with rigid structures. Regarding the spatial and temporal variability in the created ecosystem, the basin was monitored to determine if appropriate engineering and planning were proper through field experiment. And, during the monitoring and management phase, adaptive management was applied into comprehensive assessing and improving the performance of this created systems.

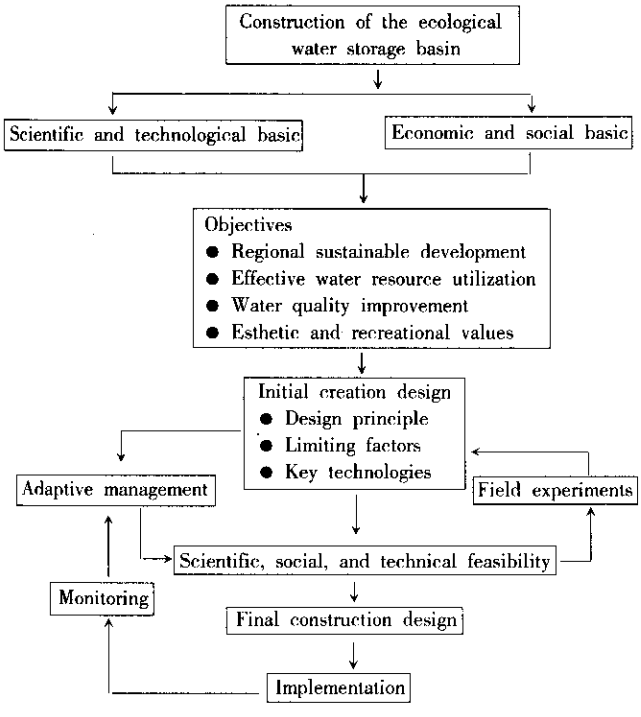

Fig.1 Flowchart for the design and construction of the ecological water storage basin

3 Designing principles for the ecological water basin

This water basin project was designed with an aquatic vegetation area of 2.8 hm^2 in the fringe of and surrounding the three islands(Fig.2), which account for 18% of the total basin. The water basin was in connection with water supply channel from Yuqiao Reservoir. About 1.5×10^5 m^3 of soil with high salinity were excavated to make the basin and ground level was dug from 3.3 m to −0.7 m(sea level). The soil was deposited on the surrounding of the site. The water depth was designed at about 3.0 m in deep-water area and at 0.3—0.4 m in planting area.

The establishment of plant community is an important part to provide various ecological services for the ecological water basin. In this region, there were three limiting factors for the growth of plant: (1) Being saline before the construction, the soil has a high salinity of 4.7%. The

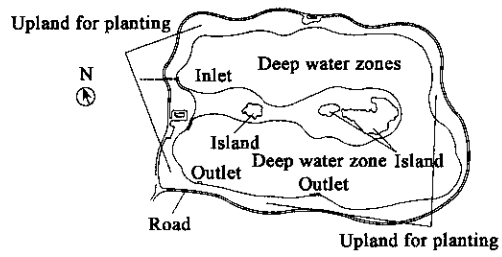

Fig.2 View of the ecological water storage basin in TEDA

permeability of the soil was very low, about 3.65×10^{-8} cm/s, the soil was difficult to desalinize naturally. (2) Because very few natural aquatic plants existed near the basin, it was not possible for aquatic plants to spread naturally. (3) The area is windy. Big waves were often observed on the open water in the windy days. They can cause bank erosion by washing the soil from the planting area and affect the growth and colonization of plants. It was particularly critical in the early stage of construction.

To overcome these difficulties, the following measures were carried out to assist the establishment of plant: (1) Soil amendation: the original soil in the planting area was replaced with the sediment of Beitang Reservior at the depth of 60 cm for hydrophytes growth. (2) Impermeable membrane isolation: high-density polyethylene membrane, about 17877 m^2, was laid under the newly filling soil in March 2003 to prevent the salty runoff from surrounding soil to the planting areas. (3) Wooden breakwater installation: wooden breakwater, with the height of 40 cm, were built between deep-water area and planting area to alleviate the impacts of big wave in April 2002. Stakes were inserted into the soil and arranged at intervals of 5 m. Two boards were paralleled and fixed on two stakes with small space. (4) Freshwater soaking: To prevent salt water from harm to freshwater macrophytes growth, water level was regulated to below to the level of planting area, 2.6 m, before October 2002. During this period, the chloride content in water reached to over 1200 mg/L. Afterward, the water level was kept in 3.0 m to meet the need of macrophytes growth when the chloride concentration was low to 100 mg/L. (5) Macrophytes planting: Freshwater macrophytes, as preferential species, were introduced into this water basin by human beings. So investigations at some natural wetlands were done for selecting preferential species that was accommodated to the local condition in this region in June 2001. In Tianjin, there includes 26 species belonging to 16 families. Then, according to the principle of water-quality improvement, salt-resistant and wind-persist, 8 preferential species in this region were selected(Fig.3, Table 1 and Table 2).

4 Effects of the ecological water source basin construction

4.1 Salinity reduction

Chloride concentration in water is an indicator of salinity

transport from the sediment to water. After freshwater introduced into the salty basin, the chloride concentration increased sharply to 9548 mg/L in 23 d. Then, the water was completely pumped from the basin. This process was repeated in next 20 d, from 24 May to 6 June, and the chloride concentration reached to 11600 mg/L. After the freshwater introduction for the third time, the chloride concentration kept relatively stable between 1000 mg/L and 1400 mg/L (Fig.4). In March 2002, the water was changed once more. In September 2002, all salty water were pumped out and freshwater were reintroduced. The basin started operation to provide source water for the water plant and the chloride concentration was kept at less than 100 mg/L.

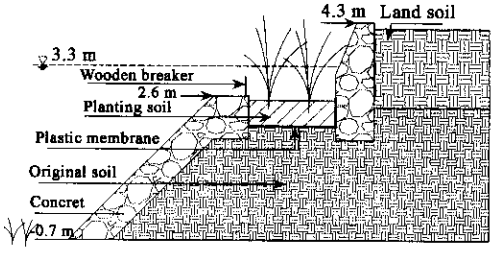

Fig.3 Cutaway view of the ecological water storage basin

Table 1 The zonation of the ecological water storage basin

Item	Area, m^2	Area percent of the basin	Measures taken
Emergent plants	11327	7.6	Soil amendation, breakwater installation, membrane isolation, planting
Floating-leaved plants	8253	5.5	Soil amendation, break-water installation, membrane isolation, planting
Deep water zone	100000	66.7	Freshwater soaking
Island	5000	3.3	Soil amendation, planting
Rocky zone	17000	11.3	No action

Table 2 Plant species and number introduced to water basin in April 2002

Species	Number	Area, m^2	Planting method
Phragmites australis	17400	4350	Rhizome, 30 cm
Typha orientalis	14640	3660	Rhizome, 30 cm
Acorus calamus	12948	3237	Rhizome, 30 cm
Nymphaea candida	22998	3833	
Nelumbo nucifera	17680	4420	
Scirpus validus	50	13	
Zizania caduciflora	50	33	
Eleocharis dulcis	50	34	
Total	85666	19580	
Number of introduced taxa	8		

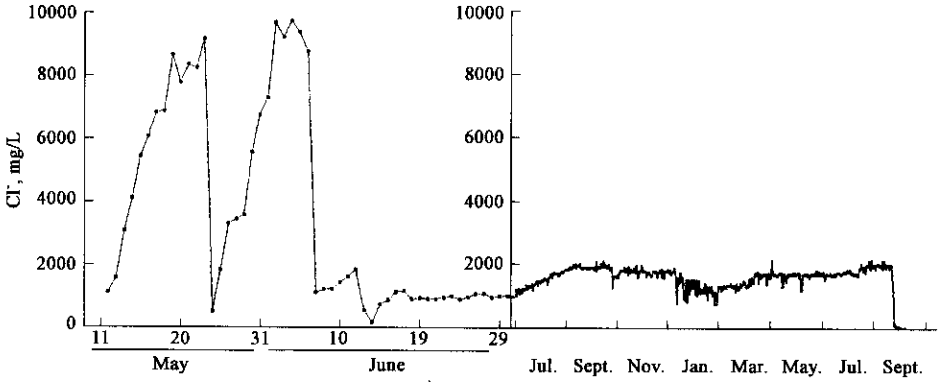

Fig.4 Cl^- concentration in the ecological water basin from May 2001 to Sept. 2002

The original content for chloride in sediment were average 2.1% in the depth of 30 cm (Fig.5). After 11-month soaking, the chloride content decreased to 0.21% in the surface and 1.65% in the bottom with an "s" shape in the sediment profile on April 13, 2002. The chloride content in sediment decreased to 0.11% in the surface and 0.58% in the bottom in the sediment profile on September 18, 2002. The average chloride content of 30 cm sediment decreased from 2.1% to 0.35%.

4.2 Biological diversity increase

Conditions of the introduced macrophytes were investigated. It was found that all introduced plants survived. The aboveground biomass for the three main species increased (Fig.6). The aboveground biomass increased 13-fold for *Phragmites australis*, 1.5-folds for *Acorus calamus* and 1.4-folds for *Typha orientalis*, respectively.

After two growth seasons, the number of macrophate taxa increased to 19 species in Sept. 2003. The newly

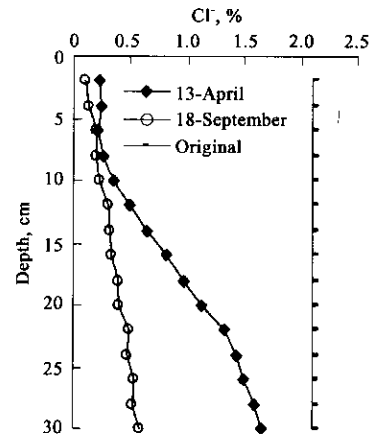

Fig.5 Chang of chloride content in basin sediment

occurred species included *Potamogeton pectinatus*, *Zannichellia palustris*, *Polygonum hydropiper*, *Paspalum paspaloides*, *Myriophyllum spicatum*, *Alternanthera philoxeroides*, *Scirpus planiculmis*, *Echinochloa caudate*,

Echinochloa colonum, *Artemisia selengensis*, and *Eclipta prostrata*. The *Myriophyllum spicatum* were thriving in the deep-water zone where no macrophytes were introduced. The growth and propagation of plant is successful.

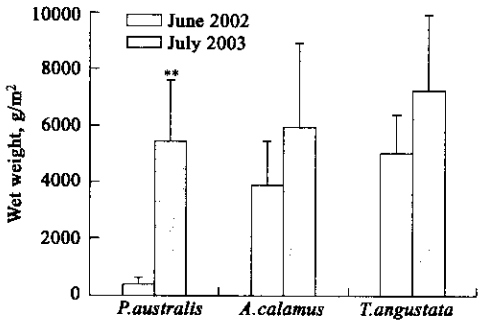

Fig.6 Mean + 1SE aboveground biomass for three species in the basin in June 2002 and July 2003. A double asterisk(**) indicates a significant difference ($P < 0.01$) according to the Student's t test

Several wild geese and mallard were observed in the ecological water basin in 2003. And, the mallard has naturally propagated. The grass carp about 100 kg were introduced to control the growth of submerged plant in July 2003. Furthermore, some waterfowls were frequent observed this area without classifying the species. A problem appeared that there were a huge number of mosquitoes in June 2003. In August, the number of mosquito greatly decreased when many dragonflies appeared.

4.3 Water quality stabilization and improvement

It was expected that the vegetation should not be harmful to the water quality. To identify the effects of vegetation on water quality, some parameters were determined by sampling and analyzing the outflow and the inflow water every month from October 2002 to November 2003(Fig.7).

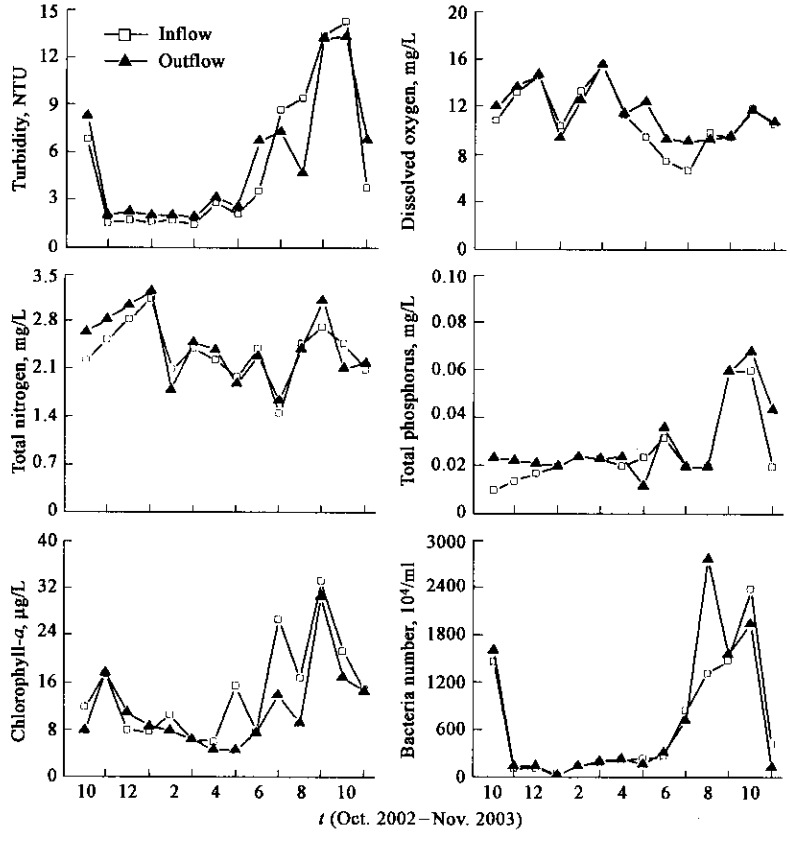

Fig.7 Main parameter of water quality between inflow and outflow in the basin from Oct. 2002 to Nov. 2003

In the survey periods, turbidity slightly increased from inflow to outflow between Oct. 2002 to Jun. 2003, while decreased between Jul. and Nov. 2003. Dissolved oxygen increased and chlorophyll-*a* decreased from inflow to outflow in 2003. Total phosphorus, total nitrogen and bacteria number decreased between May and Sept. 2003. The result showed that water quality was improved, particularly in growth season of plant.

5 Conclusions

Under the principles of ecological engineering and civil engineering, we proposed the design of this ecological water storage basin, with the volume of 5.0×10^5 m^3, on the coastal saline in an urban area. This project demonstrated that the design principals and techniques of ecosystem creation focused on the establishment of plant community. Researching into the local conditions, engineering measures were constructed, including fresh water soaking, water breaker construction, plastic membrane installation, and soil amending. It was found 8 planted species and 11 unplanted species, occurred in this project over two seasons. Wild animals were also observed. The biological diversity increased. This new ecosystem played a good role in water quality improvement.

Acknowledgements: The authors gratefully thank Shuqin Sun for the assistance with sampling and analyses.

References:

Breaux A M, Day J W, 1994. Policy considerations for wetland wastewater treatment in the coastal zone: a case for Louisiana[J]. Coastal Management, 22: 285— 307.

Casagrande D G, 1997. The human component of urban wetland restoration[M]. In: Restoration of an urban salt marsh: An interdisciplinary approach. Bulletin Number 100, Yale School of Forestry and Environmental Studies(D. G. Casagrande ed.). New Haven, CT: Yale University. 254—270.

Kadlec R H, Knight R L, 1996. Treatment wetlands[M]. Boca Raton, FL: Lewis Publishers. 893

Mitsch W J, Horne A J, Nairn R W, 2000. Nitrogen and phosphorus retention in wetlands-ecological approaches to solving excess nutrient problems[J]. Ecol Eng, 14(1—2): 1—7.

Mitsch W J, Wilson R F, 1996. Improving the success of wetland creation and restoration with know-how, tome, and self-design[J]. Ecol Appl, 6(1): 77—83.

Mitsch W J, Wu X, Nairn R W *et al*., 1998. Creating and restoration wetlands: A whole-ecosystem experiment in self-design[J]. Bioscience, 48(12): 1019—1030.

Rybczyk J M, Zhang X W, Day J W *et al*., 1995. The impact of Hurricane Andrew on tree mortality, litterfall, nutrient flux, and water quality in a Louisiana coastal swamp forest[J]. Journal of Coastal Research, 21: 340—353.

Simenstad C A, Thom R M, 1996. Functional equivalency trajectories of the restored Gog-Le-Hi-Te estuarine wetland[J]. Ecol Appl, 6(1): 38—56.

Xiao Y T, Zhang J J, Wu M *et al*., 2001. Pollution of water resource and the safety of drinking water[J]. Resource and Environment in the Yangtze Basin, 10(1): 51—59.

Zedler J B, Weller M W, 1990. Overview and future directions[M]. In: Wetlands creation and restoration: the status of the science(J.A. Kusler and M.E. Kentula ed.). Washington, D.C.: Island Press. 405—413.

Zhang X, Feagley S, Day J *et al*., 2000. A water chemistry assessment of wastewater remediation in a natural swamp[J]. Journal of Environmental Quality, 29: 1960—1968.

(Received for review March 23, 2004. Accepted May 16, 2004)

Introduction to author's research group

This paper is an contribution of Water Environment and Ecology Group of the Research Center. The group lead by Prof. Dr. Chengqing Yin focuses their research on lake eutrophication and its control, wetland science, diffuse pollution in urban and rural regions. They have conducted long-term researches for experimental studies in watershed level by several Chinese lakes. Their research results of finding "multipond system" and "ecotone structure" have achieved international recognition and received international awards. The major research projects on conduction are: Restoration and protection of lake shore ecosystems, mass flux processes in a heterogeneous landscape and space structure complexity, mechanisms and impacts of lake eutrophication, development of technologies for urban nonpoint pollution control and engineering demonstration.