Research review on the treatment of urban landscape lakes

LI Yue-peng*, LIU Hai-yan, WANG Li-li

North China University of Water Resources and Electric Power, Zhengzhou 450011, China.

Abstract: This paper summarizes the treatment experience of eutrophication by domestic and foreign scholars. At the same time, it summarizes the basic methods to govern lakes; Based on this, we advance the basic principles of urban landscape lakes: At first, we must fully investigate lake pollution source, evaluate its pollution ecological risk; Secondly we should put forward possible measures and choose the scheme for implementation, and finally complete the real-time dynamic monitoring, establish long-term supporting policies and treatment mechanism, to ensure that the pollution of lake continues to develop in the direction of health.

Keywords: Urban; The landscape lake; Treatment

Lakes, as the land resources that are essential for human survival, can regulate river runoff, develop irrigation, provide water for industrial and drinking purpose, facilitate the reproduction of living things, ensure water transportation, improve regional ecological environment, conduct sightseeing and tourism, and develop mineral products (SONG Fei-fei *et al*. 2013). As China's industrialization and urbanization are moving ahead along a fast track, the frequent human activities have damaged the natural ecosystem including lakes. In recent years, the domestic and foreign scholars and organizations have completed the treatment activities for the lakes of different types and achieved some research findings. These research findings mainly include intercepting pollution and controlling sources, selecting the remediation methods and conducting researches on policy treatment. Some positive treatment results have been accomplished in given areas, but the treatment of urban landscape lakes is not sustainable enough and the significant research findings are still unavailable. This paper examines the lake treatment experience by domestic and foreign scholars and aims to provide the theoretical basis for the comprehensive and sustainable treatment of urban landscape lakes.

*Corresponding author. E-mail: liyuepeng@ncwu.edu.cn

1 Reasons for the pollution of landscape lakes

Generally speaking, the landscape lakes refer to those lakes only with input of nutrients, but without output of nutrients. Their pollution can be attributed to two points as follows. First, the discharge of waste water and the surface runoff of rainwater generate the organisms and the nitrogen and phosphorous nutrients in the peripheral ground surface and soil. Second, the organisms are accumulated following the death of biological communities inside lakes. For landscape lakes, their water quality is polluted in three different ways. First, the eutrophication caused by an excess of nitrogen and phosphorous nutrients takes the form of green lake water, many blue-green algae and even algal bloom. Second, the organic pollution by an excess of organic pollutants takes the form of filthy, black and even smelly lake water and lack of oxygen. Third, the impurity pollution caused by an excess of solid foreign substances like particle dusts and leaves takes the form of excessive impurity, low transparency and low aesthetics. To conclude, the urban landscape lakes can attribute their ecological damage and environmental pollution mainly to eutrophication.

As a matter of fact, the domestic and foreign scholars have performed lots of researches and practices about the lake eutrophication. Eutrophication refers to the excessive growth of aquatic plants (like algae and large plants) caused by the nutrients inside lakes, reservoirs, slowly running rivers and costal waters (usually nitrogen and phosphorous compounds). As we know, algae have an advantage over aquatic plants in the competition for nutritive salt, but an excess of nutritive salt in lakes will contribute to vigorous growth of algae, rooted plants or planktons, thus damaging the normal functions of lakes, such as stinky drinking water and change to water color. The strong reproduction and growth of many planktons or shallow rooted plants may cause lakes to become swamps, and see their sizes largely reduced. What's more, the decomposition of these plants can consume large amounts of dissolved oxygen and produce lots of soluble organisms so that water quality gets dramatically exacerbated. In the process of metabolism and death, algae can give out different algal toxins, which have the strong toxicological effects, so the lake ecosystem as a whole is threatened (ZHANG Zhen and LIU Gui-min, 2007).

2 Treatment and remediation approaches to eutrophicated lakes

Now the main treatment methods of lake eutrophication include physical, chemical and biological methods. However, there are different ways to the treatment of urban landscape lakes. Some general treatment methods are detailed as follows (ZHANG Zhen and LIU Gui-min, 2007):

2.1 Physical methods

2.1.1 Diversion of wastewater

A key contributor to the lake eutrophication is the pollution from external source. The direct discharge of wastewater as a result of the agricultural and industrial production into lakes is a major cause for the increase in the nutritive sales inside lake water. An effective solution to lake eutrophication is to improve discharge pipeline and divert the discharge of wastewater to other places.

2.1.2 Replacement /dilution of lake water

In case there is an excess of nutritive salt inside lakes, replacement/dilution of lake water can directly reduce the contents of nutritive salt of lake water and remove large amounts of nutritive salt.

2.1.3 Aeration/mixture

Such methods as mechanical stirring, air compression, water pump, and injection pump are for the purpose of aeration and promoting the water movement. In this way, we can prevent the substrate sludge from giving out phosphorous, improve oxygen condition, strengthen mineralization and reduce photosynthesis of planktons.

2.1.4 Dredging

The substrate sediments in the eutrophicated lakes are usually a nutrient powerhouse, which can constantly give out phosphorous. This process is labeled as internal load. Once external load decreases, internal load can play a complementary role so that the phenomenon of eutrophication will remain unchanged. Dredging can directly remove the nutritive sale inside substrate sludge and relieve the effects of internal load on lakes.

2.1.5 Mechanical harvesting of waterweeds and algae

The mechanical harvesting devices can be used to harvest waterweeds and algae, directly improving the ecological environment of lakes. Meanwhile, waterweeds and algae themselves can absorb lots of nutritive salt, so nutritive salt can be removed from lakes by harvested waterweeds and algae.

2.2 Chemical methods

2.2.1 Deepwater aeration technology

Large amounts of nutritive salt can lead to the excessive reproduction of algae and planktons, the sharp decline of dissolved oxygen and even the anaerobic phenomenon on the interface between water and substrate sludge. The artificial deepwater aeration can increase the concentration

of dissolved oxygen when the stratification of waters remains intact. In addition, this technology can decrease the concentration of ionic substances like ammonia, nitrogen, iron and manganese and change the anaerobic condition for better. The oxygenic aeration technology was once used in Beijing Shichahai Park. Specifically, oxygen is pumped to the lake bottom and change the reduction condition of lake bottom to oxidation condition so as to reduce the release of nutrients from substrate sludge. For instance, eight aeration devices (15HP) were arranged within one 4 km-long section of Beijing Qinghe River during the 1990 Asian Games for the purpose of artificial aeration. Within the period from August 26 to September 29, the unpleasant smell was almost removed, and the water color was improved noticeably. About 60% BOD_5 was removed and DO within the aeration area increased from zero to 5-7 mg/L and DO within the peripheral zone rose to 4-5 mg/L.

2.2.2 Inactivation of nutrients

The aluminum salt and inorganic particulate phosphorus can be used to achieve precipitation and lower the contents of phosphorous in lake water. In fact, ferric salt (chloride salt or aluminum salt), aluminum ferric sulfate, sludge particles and lime slurry all have similar functions. Calcium salt is an effective inactivating agent of nutrients. In the United States, the product-CLEAN-FLOLAKE2CLEANSERTM is the mixture of calcium sulfate, aluminum sulfate and boric acid. It can cause the precipitation of iron and phosphorous, and lower the contents of nitrite and manganese. It has successfully eliminated algae and other aquatic plants in many lakes and reservoirs. SUNA-3 buffering comprehensive algaecide also falls into the category of these products. This algaecide uses the environment-friendly compositions like sodium bicarbonate, sodium hydroxide, calcium hydroxide, sodium carbonate anhydrous and sodium acetate anhydrous, which are mixed together at given proportion. These raw materials differ in main or supportive functions inside water, but can all inactivate nutritive salt.

2.3 Biological methods

2.3.1 Remediation technology of aquatic plants

The aquatic plants that are suitable for the corresponding lake environment and their symbiotic micro-environments are used to get rid of the contaminants in lake water. The growing aquatic plants may effectively absorb and concentrate the nutritive salt in water and substrate, and play a role as “nutrition pump” and “nutrient powerhouse”. Aquatic plants and planktonic algae are competitors when it comes to the use of nutrients. This technology can effectively suppress the growth of planktonic algae and artificially create the community of aquatic plants that meets the water characteristics well so as to reduce the concentration of suspended substances, increase the transparency of waters, guarantee a favorable environment for other living things, and improve the biodiversity of aquatic ecosystem. What’s more, it can create and maintain the biomass of aquatic plants, transfer the nutritive salt like nitrogen and phosphorus, achieve the effective allocation of nutritive salt by restoring such aquatic plants as floating plants, emerged plants and submerged plants to prevent the excessive growth of one dominant plant and preserve the purification capacity of waters.

2.3.2 Remediation technology of aquatic animals

In the ecosystem of lakes and reservoirs, algae can be controlled not just by nutrients, but as one part of food chain, by zooplankton and fish. Therefore, we can improve the water quality of lakes and reservoirs by regulating food chain. Since the 1980’s, many western countries have used the traditional biomanipulation technology by breeding the fierce fish in the treatment of eutrophicated lakes and reservoirs to decrease the biomass of algae. Later, Chinese scholars including XIE Ping and LIU Jian-kang proposed the non-traditional biomanipulation technology to control blue-green algae and even algal bloom. The biomass of algae is directly reduced by the filter-feeding fish (chub and bighead carp) that feed on planktons to control the lake eutrophication.

2.3.3 Biomembrane technology

Based on the natural materials or artificial media with large specific area, the mucoid bio-membrane on the surface is used to purify the contaminated waters. Large quantities of microbes concentrated on the carrier can effectively block, absorb and degrade the contaminants. JI Rong-ping and other scholars use the artificial media to collect microbes, and the removal rate of TN and TP is 22.1% and 60.7% respectively.

2.3.4 Biological floating bed technology

The aquatic/terrestrial plants or the system for stuffing biological carrier float on water surface of lakes or ponds to purify water. The nitrogen, phosphorous and other detrimental substances of the eutrophicated waters can be reduced through the plants' absorption and the species' competition and restriction so that a favorable environment is created for the multiplication and growth of different creatures and the aquatic ecosystem can be rebuilt and restored within limited area. As the inflow load is decreased, it is compulsory to create an intra-lake treatment ground in the hope of completing the effective water purification. This remediation method of lake water was successfully used in Japan's Xiapu Lake. In fact, China also achieved preliminary success through technological cooperation in the research and demonstration of Meiliang Bay and Wuli Lake Area when an attempt was made to restore the water environment of Taihu Lake.

2.3.5 Remediation technology of microbes

LI Zheng-kui, PU Pei-min and other scholars (LI Zheng-kui and PU Pei-min, 2001) have made some progress in their research on utilizing the natural pollution-free nitrogen cycling bacteria that inhabit at the roots of aquatic plants to solve the tough problem of "eutrophication" in lake water. An enterprise in Sichuan developed the "photosynthetic bacteria" to deal with the lake "overnutrition" (SHEGN Li, 2013). Technologically, the biological flora "photosynthetic bacteria" are introduced into the lake water troubled by eutrophication and the aquatic food chain is used to remove the eutrophicated substances from lakes or reservoirs. The "synthetic bacteria" can transform the eutrophicated substances into the membrane-like bait, which can become the food for small aquatic creatures. Then the filter-feeding fish can be introduced to feed on these small aquatic creatures so that the nutrients like carbon and nitrogen can be significantly reduced. As the company leader Li Jian introduced, this technology has been used in the treatment of five lakes including the artificial lake of Chengdu High-Tech Enterprises Incubation Park and Wenzhou Baicui Lake. After the treatment process, these lakes can have Type III water quality. The whole treatment process roughly involved a cost of 20 000 yuan/mu, about 40% of the cost in the traditional treatment technology.

We have summarized some basic methods to deal with lake eutrophication problems. Currently, several treatment methods are often used at the same time. Some noticeable results have been achieved in the classic lake treatment in China and abroad (TU Jian-feng *et al.* 2007; LIU Zhao-xiao *et al.* 2007; TAO Qi-zhong, 2014; HONG Zu-lan, 2007) (Table 1, 2 and 3). We can take these results into consideration during our treatment of urban landscape lakes.

The tables summarize the treatment experiences of typical lakes in China and abroad, but these treatment experiences may not necessarily apply to the treatment of urban landscape lakes. We can have a general picture of basic methods and strategies.

3 Regulatory policies for treatment work of lakes

3.1 Establish and improve the organizations responsible for protecting, management and treatment of lakes

To protect the ecosystem of the Great Lakes, such organizations including the Council of Governors of the Great Lakes, the Fishery Committee of the Great Lakes and the technological consultation committee have been established in the United States (TAO Xi-dong, 2009).

3.2 Develop the eutrophication control standard based on the nutrient criteria

With the ecological partition of lake nutrients as the basic control unit and the lake nutrient criteria as the scientific basis, the intrinsic connection and transformation mechanism between nutrient criteria and lake eutrophication control standard are examined. Based on the lake nutrient criteria within different zones, the eutrophication evaluation index system that is relevant to the urban landscape lakes is created when the effective control of eutrophication is treated as a goal and the aquatic ecosystem, human healthy, lake functions, social and economic conditions and environmental management goal are taken into consideration (HONG Zu-lan, 2007).

Table 1 Lake treatment results of Japan

Name of lake	Overviews	Treatment measures	Treatment results
Pipa Lake	This is a natural lake with water area of 670.5 km^2, water storage capacity of 27.5 billion m^3, maximum water depth of 130.6 m, average water depth of 41.2 m, drainage area of 3 174 km^2. Red tie and algae bloom happen every summer to adversely affect water supply and landscape.	(1) Reduce the inward contamination load according to the Special Measures Law of Lake Water Pollution Control; (2) Implement the Measures for Lake Water Pollution Control; (3) Implement the Provisions for the Protection of Reeds; (4) Implement the Provisions for Household Wastewater Improvement Measures;	Since these measures were put into force in 1995, the gross load of COD, nitrogen and phosphorous has been reduced by 20%, 20% and 31% separately.
Xiaodao Lake	Located at 8 km to the south of Okayama, this artificial freshwater lake was created after Ministry of Agriculture, Forestry and Fishery closed up the estuary of Xiaodao Bay. As the locked-up waters, Xiaodao Lake is featured by high concentration of nitrogen and phosphorous, excessive growth of algae bloom, red tide and water hyacinth, so the typical eutrophication happens to this lake.	The water pollution control decree was issued and the measures for controlling lake water quality included improving wastewater treatment system/rural community wastewater treatment facilities, installing the supportive facilities of joint treatment plant, installing household wastewater treatment facilities, improving wastes treatment equipment and animal wastes treatment equipment, and building artificial tideland/weed zone and plant-protected slopes, and installing water purification facilities.	Develop the water quality target and adopt water purification technology to make sure the gradual improvement of water quality on an annual basis.
Sanfang Five Lakes	As the lakes within the jurisdiction of Fukui County, Rixiang Lake has the water area of 0.9 km^2, Shuiyue Lake 4.3 km^2 and Sanfang Lake 3.6 km^2. The algae bloom mainly happens from June to September each year to damage landscape and cause water supply problems. Four types of algae that are mainly responsible for algae bloom include microcystin, anabaena, oscillatoria and aphanizomenon.	Some measures including “source control”, “inward river and canal control measures” “interior lake measure” and “lakeside measures” were taken, and the water pollution control projects of lakes and swamps included the improvement project for public wastewater treatment (Meibin public wastewater treatment project; public wastewater treatment project of special environment in Sanfang Five Lakes; publicity program for agricultural cycling lakes)	With the short-term target as the starting point, the lake water quality is improving gradually after the water quality target is established and the related projects are developed.

Table 2 Lake treatment results of Europe

Name of lake	Overviews	Treatment measures	Treatment results
Trummen Lake	The eutrophication troubles of Trummen Lake in the south of Sweden are caused by the industrial and household wastewater discharge in the context of increasing population.	The sewage diversion project did not have satisfactory results in 1958. The serious blue-green algae and algae bloom and anoxia caused the death of fish. Since 1970, the dredging work on the lake bottom removed about 60 cm of iron and sulfur-rich black and brown earth, so the gross phosphorous contents fell from 0.75 mg/L to 0.06 mg/L, and the gross nitrogen contents fell from 7.0 mg/L to 1.2 mg/L. what's more, the algae bloom has never happened again. However, the long-term monitoring result shows that large investment can't guarantee a sustainable result.	Currently, aquatic plants and creatures have been used in the water pollution control of small lakes and swamps in Sweden. Some positive results have been achieved.
Bodensee Lake	Bodensee Lake is an international lake shared by Switzerland, Austria and Germany. Rhine River flew into this lake from its southeastern end and out of this lake from its western end. From 1960 to 1970, phosphorous, that remained insufficiently treated, gained an access to Bodensee lake, thus resulting in eutrophication.	Four countries along the drainage area including Liechtenstein organized one coordination project to improve the wastewater treatment plant and perform the comprehensive wastewater treatment process with the removal of phosphorous as the key, and introduce the use of phosphorous-free detergents.	For the hard work for four decades, the concentration of phosphorous in 1999 fell to 1/6 of the level prior to 20a. after the concentration of phosphorous was lowered to 10a, the concentration of phytoplankton was reduced as well. Yet, the concentration of phytoplankton was still more than twice as much as the level in 1951.
Balaton Lake	Located 90 km to the southwest of Hungary's Capital Budapest, Balaton Lake is the largest lake of Europe. Beach and weed belt extended to the lakeside. On the southern bank are many nice swimming zones. The lake eutrophication is mainly caused by the non-point source pollution and tourists-related pollution. There are some pollution problems like ananbena bloom and undesirable taste of drinking water.	An artificial reservoir was built at the estuary of Zala River, whose drainage area constitutes half of Balaton Lake's drainage area, to control lake eutrophication. The suspended solids, nitrogen and phosphorous that access Balaton Lake from Zala River account for 90%, 75% and 50% of gross inward load. Since the project was started in 1983, the reservoir's total area has become 69 km^2.	As a result, Phase I project (the reservoir area of 18 km^2) alone has removed phosphorous by 40%-50% and nitrogen by 20%-80%.

Table 3 Lake treatment results of China

Name of lake	Overviews	Treatment measures	Treatment results
Caohu Lake	The drainage area of Caohu Lake is featured by changeable terrain, complex water system, high dense population, intense farming, and large-scale and serious pollution. Since the central government has started the water pollution control work of "Three Rivers and Three Lakes", the water pollution control work within the drainage area of Caohu Lake has made significant progress. But the current water environment is still less optimistic. The main problems include the multiple pollution sources, the overall degradation of water, bank and land ecosystem, and emerging contradiction between city and lake.	Based on the "city-lake symbiotic" philosophy, the lake water pollution control work mainly includes (1) refining functions and creating the ecological treatment and control pattern; (2) industrial upgrading to transform the mode of economic development; (3) blocking pollution and reducing load to lower the multiple pollution load; (4) water transfer and diversion to expand the environmental volume of lake; (5) maintenance and remediation to resume the ecosystem functions.	Based on the "city-lake symbiotic" lake treatment principle, Caohu Lake and other urban lakes have their water pollution problems handled so that some positive references are provided for the preparation of relevant regulations and policies for lake treatment.
Taihu Lake	The drainage area of Taihu Lake is located within the delta area along the downstream of China's Yangtze River. With a total area of 36 900 km^2, its population, GDP and fiscal revenue make up over 3%, 10% and 4% of the national total. Due to its serious water pollution, it's an urgent task to put more efforts into water pollution control work. When much attention is paid to the control of land pollution sources (industrial point source, household wastewater and agricultural nonpoint source), the ecological treatment inside lake is also a key consideration.	The eco-dredging was applied to the polluted sludge to remove the surface sediments with considerable contents of nutritive salt (0-40 m) and reduce the second pollution as released by lake sludge. When the nutrition absorbing characteristics of terrestrial plants, the feasible measures include growing the plants in water to purify the eutrophicated water, improving water landscape, strengthening the protection and construction of lake wetland, river wetland and estuary wetland, and performing the remediation of lakeside aquatic vegetation.	Taihu Lake is typically a polluted lake in China. Despite the short-term treatment results, the long-term goal is still challenging.
Dianchi Lake	Tianchi Lake, as a semi-closed lake, has entered the late years of lake development history. The present water environment problems with Tianchi Lake are mainly the shortage of water resources per capita. The challenges with water environment treatment work is to surface pollution control, lake sludge removal and large investments.	(1) An effective pollution control measure is to divert water for diluting lake water. (2) The mid-Yunnan water diversion project; (3) Rainwater and sewage diversion project; (4) Water diversion project from Niulanjiang River to benefit Dianchi lake.	The treatment of Dianchi Lake is a huge and systematic project, which takes our persistent efforts at comprehensive treatment.

3.3 Create the guarantee mechanism for controlling and reducing the total lake nutrients

3.3.1 Formulate the environment improvement-based economic growth policy with the reduction of nutrients as a goal

It is imperative to formulate the environment improvement-based economic growth policy to resolve the problems of lake eutrophication, strike a balance in the control of pollution sources, development of drainage area and economic and social development, set up the model of regional lakes planning coordination, linkage mechanism and comprehensive management and create the rational control, supervision and incentive mechanism of lake eutrophication.

3.3.2 Design special policies and laws for reducing the lake nutrients

When the guideline for different control standards of lake eutrophication is implemented, it is important to formulate the ecological and environmental protection policies within drainage area, the "anti-degradation policy", the coordination and compensation mechanism along the upstream and downstream of drainage area, the integrated management system and law enforcement supervisory system and the "suitability management mechanism" when the lake eutrophication control standard is used as the basis, and to make the comprehensive evaluation of the implementation results of these policies and management systems.

3.3.3 Establish the long-effect mechanism for the scientific innovation in the reduction and control of nutrients

It is essential to focus more efforts on the R&D and comprehensive integration of those key technologies concerning the generation and elimination mechanism of eutrophication in key lakes, nitrogen and phosphorous pollution control of water body, algae growth and plague laws, natural restoration of water body, prevention and control of swamps, and protection of hydro-fluctuation belts in reservoirs so that more scientific and technological supports can be secured for the lake eutrophication control work. Furthermore, we can perform the research on the prevention and control strategies for the loss of nitrogen and phosphorous from nutrients and to prepare the technical criteria for restrictive agricultural environment.

3.3.4 Develop the public participation mechanism for the control of lake eutrophication

With the goal of controlling pollution sources of lakes, developing drainage area and achieving the coordinated social and economic development, it is necessary to set up the model of regional lakes planning coordination, linkage mechanism and comprehensive management and create the rational control, supervision and incentive mechanism of lake eutrophication, increase the national monitoring performance for the eutrophication of key lakes and enhance the regulatory capability of local governments concerned.

3.4 Set up the technical system for lake eutrophication control and ecological remediation

It is important to investigate the reasons for nitrogen and phosphorous pollution, the precipitation process and the effects of nutrient load over nutritious conditions, the biological response of internal load in nutrients to cycling, the effects of changes to nutrients on the nutrition grade along food chain, and the stress effect of biological communities at other nutrition grades, to establish the integrated system for lake eutrophication control technology within different partitions of lakes, and the evaluation system for the lake eutrophication control technology that proves suitable for China, and to recommend the best control strategy that can guarantee water purification, habitat improvement and residential friendliness.

Outlook-some insights into the treatment of landscape lakes

We have achieved some important experiences in the lake treatment work in China and abroad.

However, the urbanization process moves ahead even faster, an increasing attention is turned to the pollution control of urban landscape lakes in our domestic urban construction. If we take a look at the lake treatment experience of different countries, we find that sophisticated technologies and previous examples can be applied to the treatment efforts of urban landscape lakes. In fact, the urban landscape lake treatment is a huge and systematic project, whose treatment strategies are indicated in Fig. 1. To guarantee the sustainable, efficient and economical treatment of urban landscape lakes, several suggestions are made available as follows:

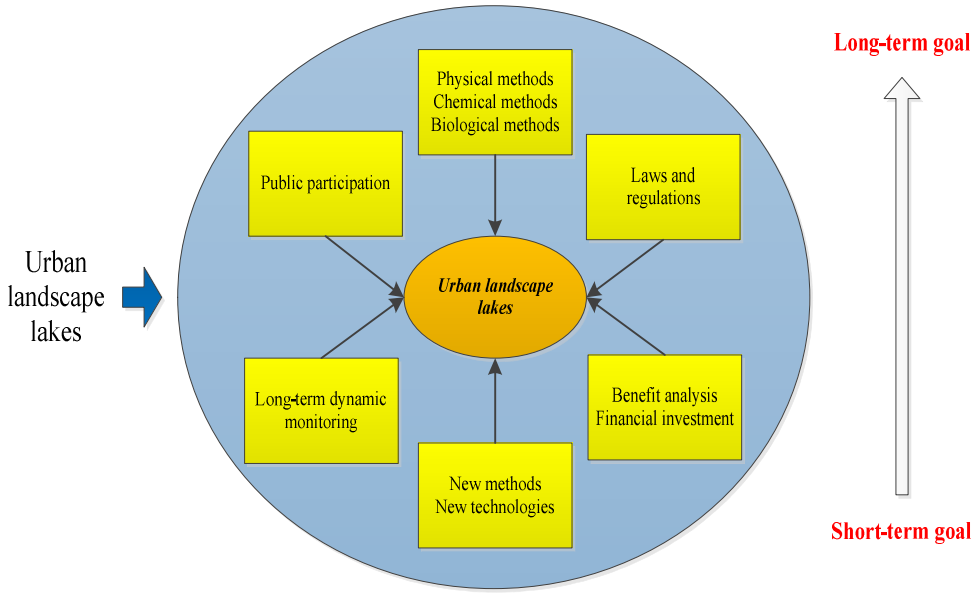

Fig. 1 Main treatment strategies of landscape lakes

First, the detailed investigation is made of pollution sources before the inward contaminants and the degree of pollution of urban landscape lakes are determined;

Second, the detailed evaluation is made of ecological risks from lake pollution after the investigation of pollution sources is completed, so as to create an index system that is suitable for different types of lakes within different areas;

Third, the remediation schemes are compared and selected when the investigation and evaluation results are treated as the basis, and the remediation system is designed after all the relevant factors are taken into account;

Fourth, the new technologies like 3S are used together with the on-site monitoring data to handle the lake monitoring work properly;

Fifth, the research is made of the regulatory policies concerning the remediation of lake environment;

Sixth, the long-effect operation mechanism is created and improved to properly cope with the relationship between long-term and short-term development, and the necessary financial sources are well ensured.

To conclude, the treatment of urban landscape lakes must follow the general principle of lake treatment. After the sources of pollution are put under control, some remediation methods can be used for ecological remediation. Once remediation is completed, much attention should be paid to the subsequent management and operation so as to guarantee the sustainable and healthy development of lakes.

References

HONG Zu-lan. 2007. Knowledge of the Dianchi Lake and idea of its water body pollution control. Yunnan Water Power, 24(1): 3-7.

HUO Shou-liang, XI Bei-dou, YAO Bo. 2009. A study of the lake eutrophication prevention and control strategies in China. Environmental Protection, 414(2): 16-18.

LIU Zhao-xiao, WU Guo-ping, XU Jian-feng. 2007. A study of eutrophication and its treatment of main lakes in Japan. Express Water Resources & Hydropower Information,

28 (11): 5-26.

LI Zheng-kui, PU Pei-min. 2001. Purification for eutrophic lake water with immobilized nitrogen cycle bacteria. Nuclear Techniques, 24(8): 674-679.

SONG Fei-fei, HU Xiao-zhen, JIN Xiang-can. 2013. Analysis of lake management strategies of different types of lakes abroad and enlightenments for China. Journal of Environmental Engineering Technology, 3(2): 156-162.

SHEGN Li. 2013. Sichuan enterprises research on "photosynthetic bacteria" to govern "nutrition" of lakes. Science and Technology Daily. http://digitalpaper.stdaily.com/http_www.kjrb.com/kjrb/html/2013-07/08/content_211667.htm?div=-1

TAO Qi-zhong. 2014. A study of the comprehensive lake treatment approach with the "city-lake symbiotic" concept-with the ecological protection and construction planning of Caohu Lake eco-civilization demonstration zone as case study. City Planning Review, (7): 50-55.

TAO Xi-dong. 2009. Experience and inspiration: Water quality management system of the great lakes region in the US and Canada. Journal of Social Sciences, (6): 25-32.

TU Jian-feng, JIANG Xiao-ping, *et al*. 2007. Research on the lake eutrophication treatment strategies in European countries. Express Water Resources & Hydropower Information, 28(14): 8-11.

ZHANG Zhen, LIU Gui-min. 2007. The progress and thinking of lake eutrophication treatment in China at present. Industrial Safety and Environmental Protection, 33(10): 50-52.