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Emerging Global Issues–Endocrine Disrupting Chemicals (EDCs) and Cyanotoxins

Saburo Matsui [1] and Hidetaka Takigami [2]

1) Kyoto University, Research Center for Environmental Quality Control Secretary of Scientific Committee of International Lake Environment Committee Foundation (ILEC)

2) National Institute of Environmental Studies, Japan

Abstract Evidences of endocrine disruption in wildlife were introduced. Possible mechanism of the function of endocrine disrupting chemicals(EDCs) was described. Clear evidence was imposex in Japanese gastropod which was induced by oragnotin contamination in the water environment. Female gasrtropod could not develop female sex organ. Other types of sexual abnormality were observed in different types of fishes, where male fishes were induced to develop the formation of eggs in male testis. Among possible causative EDCs, bisphenol A, nonylphenol, and DDT,etc are suspected major agents. However, human estrogen is found to be also causative in estrogenic activity of sewage effluents. Dioxin compounds are most strong toxic agents of multi-facets including reproductive disturbance. EDCs surveillance results in the Japanese Environment showed concentration and accumulation of them in different compartments of ecosystems.Toxic cyanobacteria occurrence is wild wide incidents in lakes and reservoirs. Difficulty of control of freshwater eutrophication is derived from massive use of nitrogen, phosphorus in agriculture as well as industries. A possible solution is diverting urine and feces at source from sewage and collect nitrogen and phophorus that is limiting natural resources. Urine control is important in terms of eutrophication and EDCs control.

Key-words EDCs Imposex Bisphenol A Nonylphenol Dioxin Cyanobacteria Eutrophication

1 Evidences of Endocrine Disruption in Wildlife

The Book "Our Stolen Future" gave a great impact on environmental scientists who have been making efforts of improving the global environment from hazard chemical contamination (Colborn et. al, 1996). Those scientists were focusing on hazard chemicals in terms of DNA toxicity, etc. which might cause cancer risk on human and wild animals, and if possible, mutation on DNA pools of living species, which was just ignoring the toxicity of endocrine disruption. The book proposed that many synthetic chemicals as well as some natural chemicals might disturb endocrine regulation mechanisms on human body as well as many wild life bodies. Among many possible types of disturbances, reproductive disturbance is so far notable with wildlife. Evidence is growing that some types of environmental pollutants that interfere with the endocrine regulation system, can possibly harm the health of wildlife species. Figure 1 summarizes those evidences from the book content and other information. Population decrease in birds, amphibians and reptiles, fishes and shellfish, and mammals are reported. Among the possible disturbances, the disturbance of sex organ development was observed e.g., male alligators in Florida with short penis, and female Gastropod

Mollusks (a type of sea snails) with longer penis. It was well investigated as a clear evidence of population decrease in gastropod mollusks in Japan, called imposex because that the female mollusks extended her penis which hindered intercourse with male mollusks. In the latter case, organotin compounds such as tributyltin (TBT) and triphenyltin (TPhT) induced imposex of the mollusks resulting in the reduction of their population around the Japanese coastal areas. TBT and TPhT, used in antifouling paints, were banned in Japan, but they are brought in along with ships from other countries. This indicates that urgent international measurers are needed against the use of organotin compounds in antifouling boats and ships.

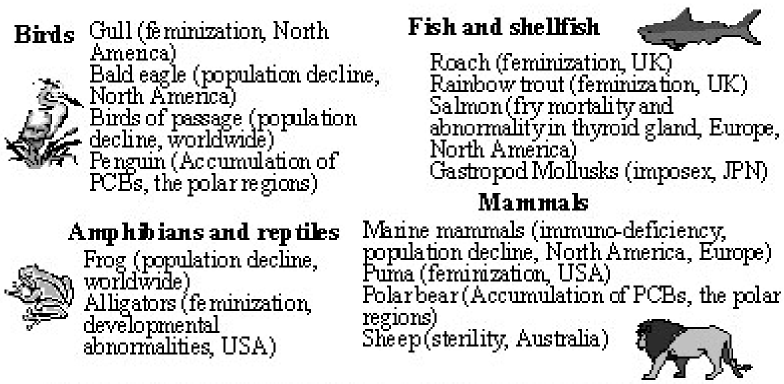


Fig. 1 Evidences of Endocrine Disruption in Wildlife

2 Possible Mechanism of the Function of Endocrine Disrupting Chemicals

EDCs can mimic or block the effects of hormones that play fundamental rolesin the body function. Risk assessment of EDCs is far more difficult than that of acute toxic substances and carcinogens. Because hormonal substances exert their effects at very low concentration in blood compared to lethal or carcinogenic concentrations. They are different from species to species, and the toxic endpoint is not merely "life or death" but abnormalities in reproductive organs and damage in neurological systems, etc. If reproductive endocrine disrupting chemicals are focused here, there are at least three ways of possible interpretation. Figure 2 shows that firstly estrogen mimics are identified such as bisphenol A, a material of epoxy resin, nonylphenol, a nonionic surfactant, and DDT,etc. They behave as an estrogen making a ligand- estrogen receptor formation that binds to specific DNA sequences that lead open of the following DNA sequences which are encoded for making special proteins that are a result of estrogen signals. They are inducing over production of proteins stimulated by estrogen, thus feminization of wildlife was enhanced. The second possible way of interpretation is that androgen antagonists are identified such as DDE, a metabolite of DDT, and vinclozolin, etc., which interfere a formation of a ligand- androgen receptor, leading anti-masculinization. The third possible way of interpretation is that inhibition of synthesis of enzymes that catalyze formation of estrogen, such as organotin, the cause of imposex with gastropod mollusks, and dioxins, multifaceted toxic effects including endocrine disruption.

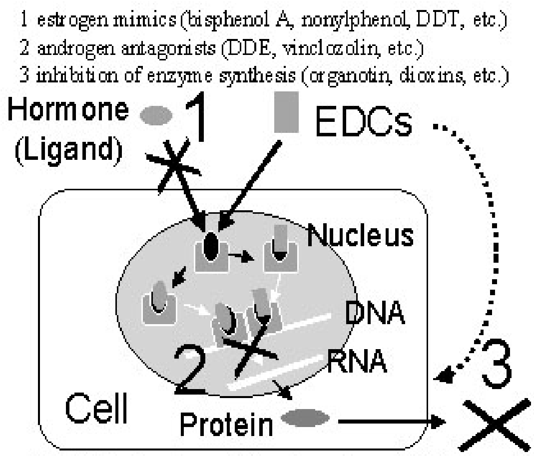


Fig. 2 Mechanism of the function of EDCs

3 Imposex in Japanese Gastropod and Organotin Contamination in the Water Environment

Horiguchi conducted survey on imposex in gastropod species in Japan coastal areas and found that Japanese gastropod mollusks showed abnormal length of female penis. He introduced a relative penis length index that is the ratio between average female penis length and average male penis length for regional groups of mollusks in Japan(Fig.3) Many indexes showed more than 60 and some 90. The mollusks are bisexual when young, but develop into different sex. The disturbance of female development makes them impossible for breeding. This phenomenon is also observed in Korean coastal areas. Organotin such as tributyltin (TBT) and triphenyltin (TPhT) are uses as anti-fouling paints for boats and aquatic nets. Those organotin liquates out and contaminates surrounding waters, which build up accumulation in gastropod mollusks (Fig. 4). The reproductive abnormality is called imposex which is now interpreted as the result of inhibition of organotin on the cytochrome P450 aromatase enzyme function that produces estron, a female hormone, from androstenedion, a male hormone. Female mollusks cannot develop female sex organ. The range of measured tributyltin (TBT) concentrations in different compartments of aquatic environments are shown in Figure 5. As shown in the figure, it is obvious that tributyltin is concentrated from water to different compartments including organisms (Weidenhaupt, et. al 1997). Although contamination of tributyltin is very low in water, the current level in water is exceeding to the level of induction of imposex with the gastropod.

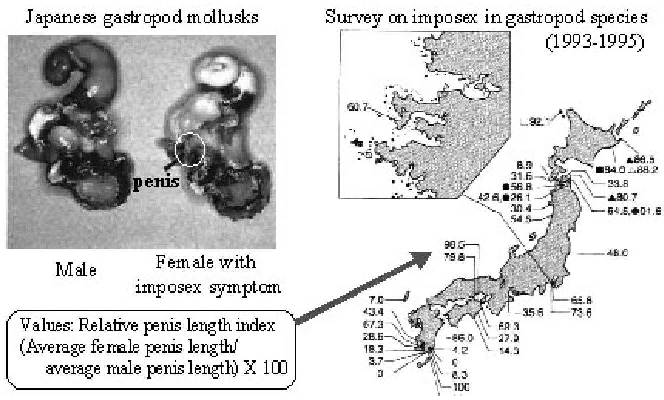


Fig. 3 Present status on imposex in Jap anese gastropods(By Horiguchi)

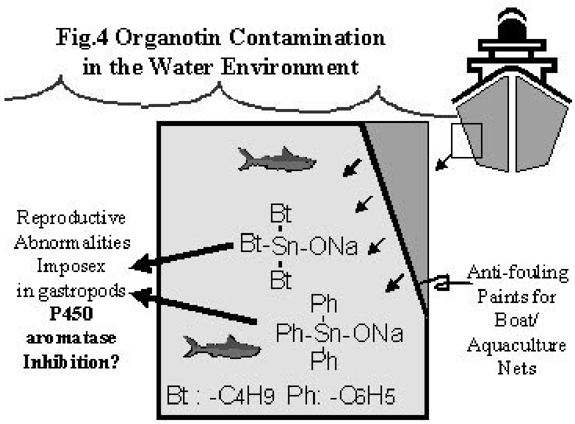


Fig. 4 Organotin Contamin ation in the Water Environment

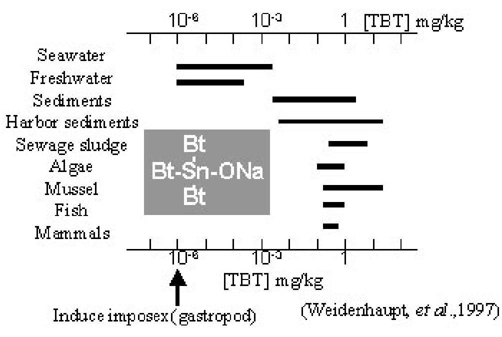


Fig. 5 Range of measured TBT concentrations in different comp artments of aquatic environments

4 The Sexual Abnormality Observed in Fish

Sexual abnormality was found with fishes in England where male rainbow trouts were stimulated to form of vitellogenin, a yolk precursor protein and causing the formation of eggs in male testis. The main route of endocrine disrupting chemicals was sewage treatment plants because the coverage of sewage works was completed in England where most of trade effluents and household waste water went sewage pipes (Fig .6). Any chemicals must pass through sewage treatment plants except non-point pollutants. Scientists firstly focused on non-ionic surfactant that is used large amount in wool industry as detergent and plasticizer in plastic industry. Non-ionic surfactant such as alkylphenol polyethoxylate is used and discharged in effluent that reaches sewage treatment plants where the aerobic biological treatment method is employed. Figure 7 shows the pathways of alkylphenol polyethoxylate. Aerobic biological treatment can decompose alkylphenol polyethoxylate into smaller molecules such as alkylphenolethoxyacid (AP1EC) or alkylphenolethoxyalchol (AP1EO) that show weaker estrogenic activity(Ahel, et. al 1994). Those chemicals can be decomposed further under anaerobic conditions to alkylphenol that shows strong estrogenic activity.

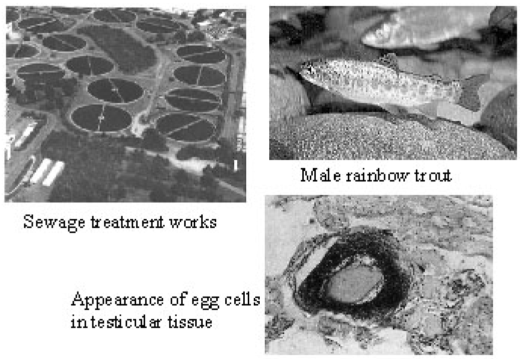


Fig. 6 The sexual abnormality ob served in fish

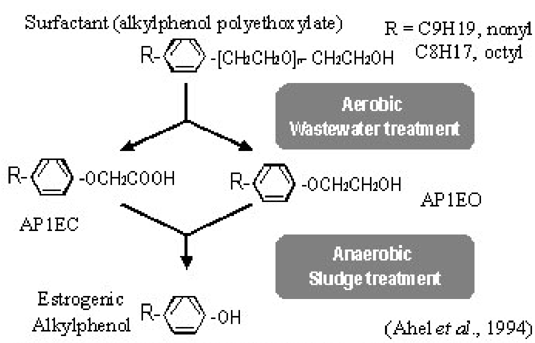


Fig. 7 Aerobic and anaerobic biotransf or mation pathways of alkylphenol polyethoxylates

5 Human Estrogen is Causative in Estrogenic Activity of Sewage Effluents

Japanese Government started a nationwide monitoring of the contamination of suspected EDCs in rivers, lakes, coastal waters as well as in some wild life species. The results showed nation wide EDCs contamination in the environment with good relationship between the amounts of EDCs used and discharged. Among the monitoring results of many EDC suspected chemicals, human estrogen contamination is also notable. 17 Beta-estradiol and estron are typical estrogen that are discharged in urine by human populations. Our investigation for three Japanese sewage treatment plants and Lake Biwa showed the concentration level of contamination by estrogen. Figure 8 shows the results that the yeast estrogen screen method gave total estrogenic activity of whole water sample and the E2-ELISA method gave the concentration of 17 Beta-estradiol in the sample (Matsui. et.al.,2000). The contamination levels are very low in the magnitude of 5–13 ng/L. The lake sample shows lower than the concentration level of the sewage effluent. However the effluent concentration level is just around the threshold concentration to trigger the formation of vitellogenin(VTG) in male fish.This result indicates us that we should not overlook the natural hormone contamination as well as synthetic EDCs. Depending the local conditions of sewage works, the treatment level of sewage work may require to be more advanced.

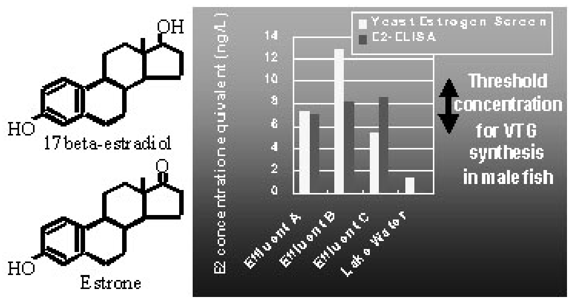


Fig. 8 Human estrogen is causativein estrogenic activity of sewage effluents!

6 Dioxin Compounds and Regulation

Among numerous harmful chemicals, PCDDs (polychlorinated dibenzo-p-dioxins)/ PCDFs (polychlorinated dibenzofurans) and PCBs (polychlorinated biphenyls) are considered as powerful toxicants in many biological functions including general toxicity, teratogenicity, carcinogenicity, reproductive toxicity and immuno-toxicity (Fig. 9). Among the multi-facets of toxicity with PCDD/Fs, the effect of endocrine disturbance shows strongest, which is expressed as malformation of sex organs of a new generation. Possible explanation is that PCDD/Fs and PCBs are toxic to cytochrome P450 enzyme systems, known to basically catalyze oxidation of toxic chemicals into water soluble and dischargeable forms, in addition of catalyzing formation of many endocrine chemicals. The oxidation process of chemicals are guided by many endocrine receptors that are suspected to be strongly disturbed by PCDD/Fs and PCBs. Figure 10 showed dioxin compounds regulation in terms of tolerable daily intake (TDI) in the world and related toxicological information (Sakai). The scale of TDI is expressed in terms of pg-TEQ(Toxicity equivalent quantity)/kg biological weight/day. PCB Yusyo disease patients were estimated to be exposed to be more than 10,000 of pg-TEQ/kg b. w./day. Animal test results indicated some important information in terms of NOAEL(Non Observable Adverse Effect Level). Compared to TDI sets by Germany, The Netherlands and Japan that are within the recommendation level of WHO, breast fed infants now take more than the set level in the world. USEPA set guideline on Dioxins based upon cancer risk that showed much stringent level than the WHO recommendation level. The understanding of chemical toxicity based upon cancer risk is different approach from the daily allowable intake one. It would be almost impossible to reach to the USEPA level by many countries, because the contamination of Dioxins have spread widly in many industrial countries. However, it is necessary not to produce dioxins and to put efforts of reducing them from the environment. Among possible many chemicals that are suspected to be endocrine disturbance, dioxins are so far the strongest.

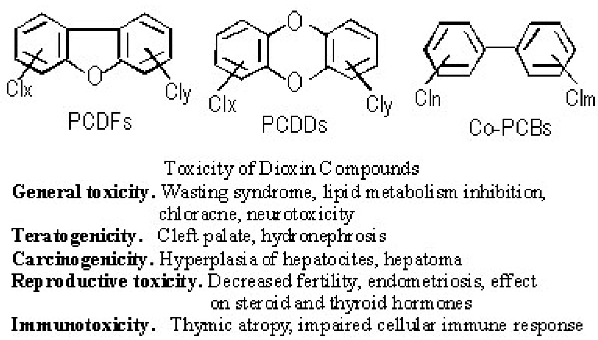


Fig. 9 Dioxin Compounds

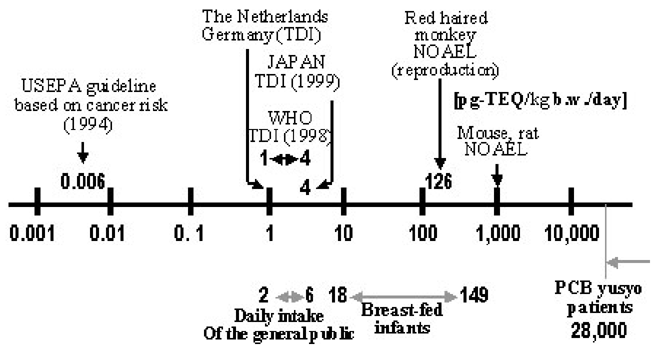


Fig. 10 Dioxin compounds regulations in terms of TDI in the world and related toxicological information (Sakai, modified)

7 EDCs Surveillance Results in the Japanese Environment

Ministry of Construction of Japan, and Environment Agency of Japan, etc have been conducting a nation wide surveillance of EDCs contamination. From the results of them, we summarize them and showed an interesting result. Figure 11 compared three chemicals such as Bisphenol, Nonylphenol and Di-(2-ethylhexyl)phtalate that is a plasticizer, in terms of contamination among water sewage, sewage sludge sediment and water organisms (fishes). All of them showed high concentration with sewage sludge, sediment and fishes. Although contamination of those chemicals in water is at very low level, they are well accumulated with other compartments. Ecological understanding of those synthetic chemicals is critical for the administration of the environment.

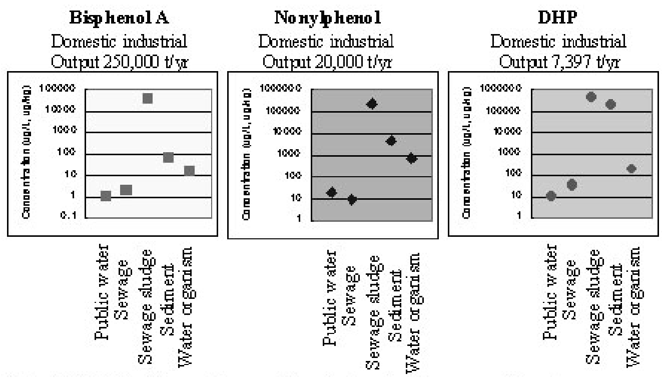


Fig. 11 EDCs Surveillance Resultsin the Japanese Environment (Reported max values)

8 Toxic Cyanobacteria in Water

Water eutrophication problems are complex depending upon local conditions. However, the common and critical problem associated with the freshwater eutrophication is blue green algae bloom and toxic emission by some types of blue green algae or cyanobacteria. The toxicity is caused by cyanotoxins that are produced by Microcystis aeruginosa and Anabaena sp. Cyanotoxins are detected in many eutrophicated lakes and reservoirs in the world. When animals as well as human drinks water containing high concentration of cyanotoxins, they get sick or even die. Toxicity of synthetic chemicals has attracted public attention among developed countries. Unfortunately, toxicity of cyanobacteria in water has not attracted public attention among developed countries, because the water purification technology almost overcome drinking water problems with cyanobacteria toxicity. Developing countries that are suffering from cyanobacteria toxicity, do not unfortunately attract public attention yet. Microcystis species and Anabena species are responsible to cyanobacteria toxicity (Fig. 12). Other blue green bacteria, cyanobacteria are responsible to emit odor substances in drinking water, if the water is not properly treated. Figure 14 showed the occurrence of toxic cyanobacteria of freshwaters of the world. The incidences are categorized in two groups such as hepatotoxic group and neurotoxic group. Most of the incidences were related with animals except the Brazilian case where city tap water was contaminated by cyanobacteria toxins - microcystin, anatoxin-a, saxtoxibs,etc. and utilized in error to the artificial dialysis, resulted in death of patients underwent by the dialysis. Figure 13 also showed a comparison between two groups of toxins in terms of toxin weight over dry weight of cyanobacterial samples from different publications. Figure 14 showed a common chemical structure of microcystin groups. Microcysytin consisits of a common sharing part that is a benzene ring with an alkylchain (Adda) and amino acids ring (Glu(iso). Mdha. Ala, beta-Me-Asp(iso)). Microcystin consists of different types of toxic chemicals such as Microcysytin LR, YR, and RR that are the strongest species among Microcysytin. The differences are minor changes with amino acid compositions of R1, R2 R3 and R4 parts. It is important to know how they are strong toxic compared to other toxic chemicals such as dioxin and tetrodotoxin that is a globefish toxin. Microcysytin LR is stronger than dioxin in terms of LD50 mouse acute toxicity.

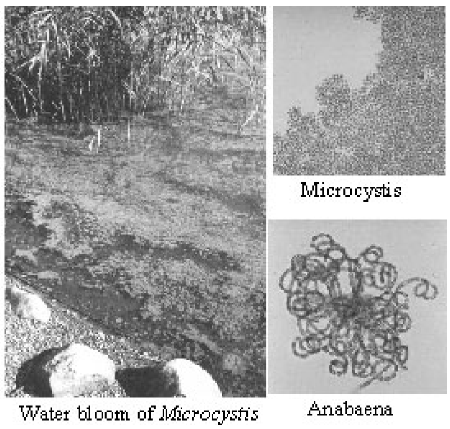
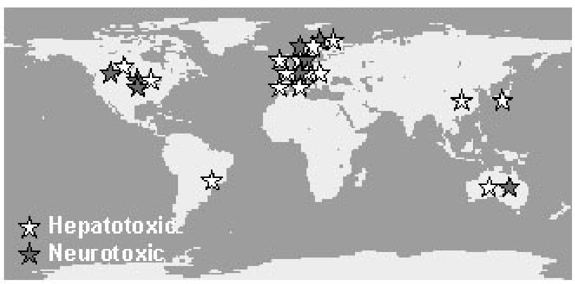


Fig. 12 Toxic cyanob acteria in water



Highest published concentrations of cyanotoxins
Hepatotoxic **Microcystin** 7,300 ug/g dw from China & Portugal
Hepatotoxic **Nodurarin** 18,000 ug/g dw from the Baltic sea
Neurotoxic **Anatoxin-a** 4,400 ug/g dw from Finland
Neurotoxic **Saxitoxins** 3,400 ug/g dw from the USA
dw: dry weight of cyanobacterial samples

Fig. 13 Occurrence of toxic cyanobacteria in freshwaters of the world

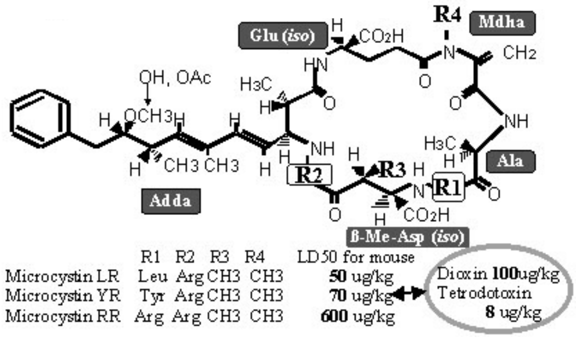


Fig. 14 Chemical Structure for Microcystin

9 Difficulty of Control of Freshwater Eutrophication

Many developed countries have been putting efforts of controlling freshwater eutrophication introducing denitrification and phophorus removal techniques in sewage treatment as well as industrial treatment, controlling chemical fertilizer application in agriculture, etc. However, the results are still insufficient. Figure 15 showed results of efforts in Great Lakes and Lake Biwa in terms of nitrogen control. A comparison of annual variation of nitrate-plus-nitrite concentration between Great Lakes and Lake Biwa is indicated. There are no decrease in nitrogen contamination levels between them after incidents of algal bloom followed by the improvement of point source control.

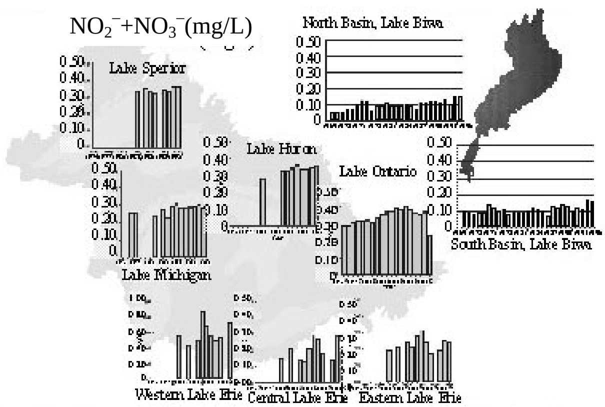


Fig. 15 Comparison of annual variation of Nitrate-plus-Nitrite Concentration between the Great Lakes and Lake Biwa (Neilson et al.1994)

Lake Biwa is still suffering from Microcystis bloom every year although due to a water purification technique, there is no significant problem with drinking water by Microcystins. Both southern and northern parts of Lake Biwa exceed stream standard of nitrogen that is 0.10 T-N mg/L. Phosphorus concentration of southern Lake Biwa also exceeds the stream standard that is 0.01 T-P mg/L, in spite of stringent point source control introduced. Non-point source control is now under focal points of discussion which mean that agricultural chemical fertilizer control and storm water run-off from road are important subject to be tackled.

10 Conclusion

Lakes and reservoirs are closed water bodies where once contamination takes place it is very difficult to clean it, resulted in many possible ecosystem disturbances. This kind of anxiety became true with the contamination by endocrine disrupting chemicals (so called environmental hormones). Some types of toxic chemicals are persistent organic pollutants (POPs) because they persist for a long time in both water and sediments, thus increasing the risk of exposure to aquatic organisms as well as human who depend on drinking water and fish from lakes. (EDCs) and cyanotoxins fit in the POP category and are emerging as global issues, because they are showing new aspects of toxicity. EDCs as well as other type of toxic chemicals are so numerous that it is indeed very difficult to control. We humankind can find only two ways of control, one is source control that we can decide either no production of such toxic chemicals or vary careful control of the use of chemicals in minimum amount. The second way is that the use of chemicals is allowed, but must treat well in spite of high cost. We can find solutions along these lines. Chemical producers and users and final consumers all are responsible to those synthetic chemicals. What about pharmaceutical chemicals that are used with human and animals and discharged in urine and feces. Can modern sewage treatment treat them safely? The answer is no. Green Revolution that took place during 1960s–1970s were very successful to overcome starvation by the introduction of new species of crops, massive use of pesticides and chemical fertilizers. It is time to look at the consequences of Green Revolution. Eutrophication is one of the negative consequences of the Revolution. We have to seek another revolution that is Blue Revolution for clean and safe water.

What is the situation of nitrogen, phosphorous and potassium that are essential agricultural fertilizer? Among them phosphorus is very limiting natural resource more than petroleum.We have to deeply think the future of our planet that we must not deplete natural resources before complete dissipation. Phosphorus must be collected from human urine and recycled to agriculture fertilizer. This approach is very promising to Chinese society because only Chinese civilization introduced human excreta as agricultural fertilizer while other Egyptian, Mesopotamian and Indus civilizations did not utilized it. Sustainable society means resource reuse and recycle society. Human urine contains more nitrogen, phosphorus and potassium and feces so that collection of urine from human at source must be taken. Western style sewage works is only available where water resource is abundant while west part of China is obviously water resource limiting area. If human urine and feces are successfully diverted from gray water, it is promising that less water supply and less sewage water so that sewage work become much ease to collect and treat, resulted in control of eutrophication (Matsui, et al., 1999). Human hormones discharge as well as pharmaceutical discharge in urine must be properly treat in order not to disturb ecosystems. EDCs and cyanotoxin issues provided us an opportunity when our society is not sustainable if we think the current society system is ideal. Western society is not an ideal society for our planet as well as the current oriental society.

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Eutrophication Experience in the Laurentian Great Lakes

Murray N. Charlton
National Water Research Institute, Environment Canada, Burlington, Ontario, Canada

Abstract The experience in controlling nutrient pollution in the Great Lakes was generally positive. Scientific predictions about the degree of phosphorus load reduction needed were mostly accurate. Simple technologies of phosphorus precipitation and replacement of detergent phosphorus were successful. Enhanced technologies of sewage plant optimization and perhaps filtration will be needed in some areas to maximize restoration. Non-point source nutrient control has been largely driven by economics and is still a large problem. Restoration of embayments and harbours requires very stringent nutrient control. The concentration of agricultural waste from industrial type feedlots is a growing concern. The control of eutrophication appears to be an ongoing problem well into the future.
Key-words Great Lakes Phosphorus Algae Agriculture Non-point sources

1 Introduction

The history of European settlement in the Great Lakes area extends back only 150 years. Progressively, the forests were cleared and more and more land was used for agriculture. Eventually, cities and industrial activity developed that used the Great Lakes for transport . Deforestation led to non-point source pollution of the lakes by erosion and by agricultural chemicals. Initially, the growing cities had a small effect but eventually the use of phosphate based detergents and the advent of sewage collection systems caused a large increase in phosphorus load to the lower Great Lakes. A joint plan to reduce nutrient loads in the Great Lakes Water Quality Agreement (GLWQA) in 1972 between the governments of the USA and Canada resulted in less phosphorus load and better overall water quality especially in Lake Erie and Lake Ontario. There remained 43 areas of intense pollution and specific emedial Action Plans were constructed for the ongoing restoration of these areas. Non-point source pollution is a continuing problem both from agriculture and cities. Phosphorus is thought to be the main limiting nutrient in the area.

2 Lake Erie

The Lake Erie eutrophication situation is probably the case most recognized internationally from North America. Building on the increased load caused by deforestation and agriculture there was a sharp increase in phosphorus load in the period 1940 to 1970 (Chapra, 1977) with the use of detergents, increased population, and increased numbers of people served by inadequate sewage plants. Already by the late 1920s there were problems of water quality and fish availability. By 1970 there were intense algal blooms and oxygen depletion problems that stimulated much public concern. Finally, there was an understanding that there were large anthropogenic changes that must be reversed; The GLWQA between Canada and the U.S. was the result. Phosphorus load reductions of roughly 50% were integral to the agreement.

The agreement was successful in that phosphorus loading decreased by more than 50% by the mid 1980s in Lake Erie as illustrated by Figure 1 using data from Dolan, 1993, Fraser, 1987 and Lesht et al. 1991 and Dolan, D.M. personal communication. This was achieved by constructing new sewage plants and by instigating phosphorus precipitation at existing plants. A key step was the phase out of phosphate builders for detergents which amounted to about 25% of the load. All large sewage plants were to have an effluent total P of no more than 1 mg/L. The majority of the load decrease came from reduced municipal sources via sewage plants.

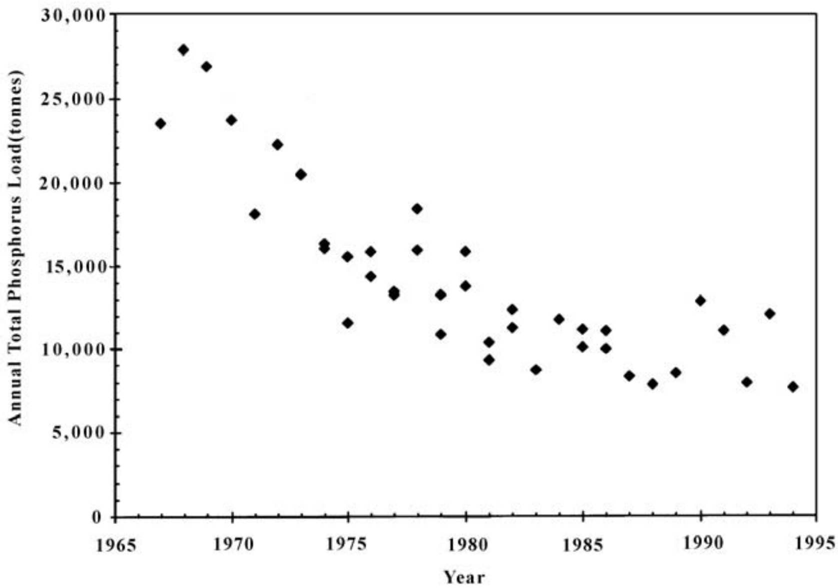

Fig. 1 Annual total phosphorus load in Lake Erie

The effect of the phosphorus load change was unevenly distributed in Lake Erie. There is a strong west to east gradient in concentrations of phosphorus and algae which is consistent with most of the load occurring in the west basin (Charlton et al. 1999) even today. This is consistent with high agricultural loads and the remaining substantial load from cities in Michigan and Ohio. The reduction in nutrient load had the most effect on the west basin. In the period of nutrient reductions between 1968 and 1988 total phosphorus decreased by 5.7 μg /L in the west basincompared to 2.8 μg/L in the east basin and chlorophyll decreased by 5.5 and 2.1 μg/L respectively (Charlton et al. 1999). Because most of the recovery occurred in the west basin, I speculate that the majority of the damage due to increasing loads occurred in the west basin. The recovery has, however, not been full. There remain substantial nutrient loads from sewage and agriculture far above those of pre-European times. It is estimated that non-point source phosphorus loads now make up about one half of the total since municipal loads have been reduced. The ability of these loads to grow algae in the lake is complicated by the fact that much of the phosphorus is in eroded soils. Thus, much can be lost to sedimentation before algae can be stimulated. Control of agricultural runoff has been a slow process with much left to be done.

Nitrogen contamination has developed differently than phosphorus. Nitrogen is not removed to a large extent at sewage plants whereas the removal of phosphorus can exceed 90%. Thus, the amount of nitrogen discharged in sewage has likely increased while the algal demand has decreased due to decreased phosphorus in the water. In addition, there are non-point sources from the atmosphere and runoff from agricultural operations. The result has been a steady increase in nitrate in Lake Erie and the other Great Lakes. In terms of mass, the increase in nitrate has been one of the largest man-made changes. Lake Erie nitrate has increased by 0.44 mg/L in the west basin and 0.22 mg/L in the east basin since 1968 (Charlton et al. 1999). That these changes are largest in the west basin is consistent with the notion they are related to the decrease in municipal phosphorus load but other sources cannot be discounted. As yet, there does not seem to be any environmental effect at the ambient concentrations. Nevertheless, the nitrate increases are another sign of the ability of un-recycled nutrients to alter the lake environment.

In the late 1980s Lake Erie was colonized by zebra mussels thought to have arrived in ballast water in ships from Europe. Now both Lake Erie and lake Ontario show localized signs of the filtering effect of the mussels. In terms of productivity it is likely that the nutrient load reductions made the most difference in the last 30 years with exotic mussels effecting the most change towards clearer water in the west basin of lake Erie and in embayments (Charlton et al. 1999).

In general, the experience in Lake Ontario has been similar. Phosphorus load was cut in half and concentrations in the water decreased by half. Before significant P load reduction, spring concentrations were about 20 μg/L and about one half of that was soluble reactive phosphorus. Now, soluble reactive P is almost undetectable and total P is typically 10 μg/L. One main difference between Lake Ontario and Lake Erie is the nutrient load is spread more evenly around Lake Ontario–thus the results of nutrient reduction have occurred more or less evenly in the lake. Most discharges are close to shore within the first two km; about the same distance offshore as the water intakes for drinking water. There is a tendency for higher nutrient concentrations near shore. As the volume of treated sewage flows increase there may again be a long term degradation of near shore quality. This is because the treated sewage P concentration is 500–1,000 μg/L whereas the desired in-lake concentration is 10 μg/L. Thus, treated sewage is very active biologically and the dilution characteristics of the near shore govern the concentrations to be found there. Increased volumes of sewage may have to be both treated better as well as discharged further from shore.

One of the targets of the nutrient controls was the elimination of obnoxious algal blooms and elimination of obnoxious accumulations of the attached alga Cladophora. Paradoxically, there have been blooms of Microcystis spp. in west Lake Erie and the shallow east basin of Lake Ontario lately. These may relate to the amount of grazing pressure exerted by the exotic mussel population on other smaller algae species and the still considerable nutrient load. Cladophora seems to be stimulated by zebra mussels as the mussels excrete soluble nutrients that can be readily assimilated. This, plus the increased clarity of some waters allowing photosynthesis to greater depths, can result in a prodigious Cladophora accumulation on shorelines even if the density per unit area is not large. Recently deleterious accumulations of Cladophora have occurred on some Lake Erie shorelines despite ambient phosphorus concentrations of 10 μg/L or less. Thus, the mussels have complicated the assessment of the success of nutrient load reductions and have tended to exacerbated attached algae problems that otherwise may have virtually disappeared.

Phosphorus concentrations in the Great Lakes were never very high relative to other polluted lakes around the world. Yet governments and the public were shocked to realize that they were no longer unaffected by the municipal and industrial activities. People in North America had assumed that the lakes were so large they would not be affected. Happily, once the danger signs were recognized, strong measures were taken to control point source phosphorus by about 50% and this prevented further damage. Not only has further damage been avoided but eutrophication has been reversed and systems have recovered from the worst effects. The success of the GLWQA in nutrient control is perhaps a useful example worldwide showing that cultural eutrophication can be reversed.

3 Remedial Action Plans and Lakewide Management Plans

The 1987 version of the GLWQA stressed that Remedial Action Plans (RAP) should be developed to address problems in 43 areas of intense pollution identified around the Great Lakes. The Hamilton Harbour RAP identified several eutrophication problems. Investigation of phosphorus sources revealed that further control of municipal phosphorus load from the main sewage plants and CSOs would have the fastest and most important effect on improving water quality. Further phosphorus controls were among the 50 recommendations of the Stage Two report (Rodgers et al. 1992). Phosphorus controls in the period 1970–1985 have lowered the concentration of phosphorus in the water considerably. The early annual data show a large decrease that corresponds mainly to the construction and instigation of phosphorus precipitation at the Hamilton sewage plant. These changes were largely brought about due to the initial efforts mandated under the GLWQA. Subsequent daily data show gradual downward trends until the late 1990s when a marked downward shift occurred. That latter shift corresponds to process optimization at the Burlington sewage plant.

Originally it was thought that the Burlington plant was too small to make much difference. When expansion of the plant was needed there was an intense audit of operations that revealed more loading than previously recognized. Moreover, the audit and engineering studies showed that the plant processes could be optimized to extend the life of the plant and provide better treatment. As soon as optimization was completed in 1997 we saw lower phosphorus levels in the Harbour (Fig. 2). Thus, the municipality has saved money and the Harbour has been cleaned up somewhat. While much improvement is still needed at the large Hamilton plant these results show how important good operation can be at even relatively small plants. They add impetus and hope that the phosphorus levels in the water can be brought down to the initial goal of 34 μg/L and eventually to the final goal of 17 μg/L. At the same time it must be realized that expenditures of about $600MCDN are required to improve the sewage plants–this is not a small amount locally and will take many years to mobilize.

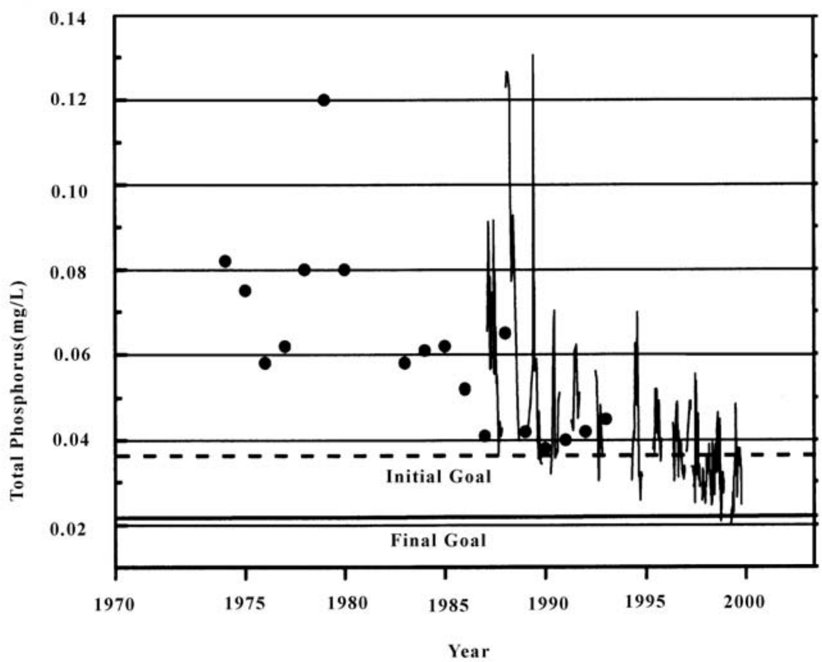

Fig. 2 Total phosphorus in Hamilton Harbour

One of the problems facing North American urban areas is the accumulation of nutrients. Food grown elsewhere, often using imported fertilizers, is transported to cities. Often, however, there is no return of nutrients to agriculture and accumulation occurs in water and soil. Higher removal efficiency at sewage plants causes the production of more sludge which must be disposed of on land. Ideally, the sludge would be used to grow more food and that is what is now happening with the sludge from Hamilton and Burlington. One problem with sewage sludge is the high water content that makes transport expensive. Technologies are now being developed internationally in sewage plants to crystallize phosphate compounds that can be used for raw material in fertilizer production. Approaches such as this are needed to ensure an efficient re-cycle of nutrients instead of a deleterious accumulation.Non-point source control has been mainly through prevention of CSO discharges. Large tanks have been constructed to capture and store CSO water until a rain event passes. Then, the stored water is pumped back into the sanitary sewer system to receive treatment at the main Hamilton sewage plant. Although these systems prevent most CSO discharges they cannot prevent discharges resulting from the largest rainstorms. Nevertheless, they have allowed some beaches to open for the first time in decades and the incidents of visible sewage discharge have decreased. Non-point source emissions from land use are being slowly addressed by stewardship programs. These are voluntary programs that encourage land owners including farmers to modify their practices to enhance stream water quality and hence the quality of Hamilton Harbour.

4 General Comments

Non-point source pollution from agriculture has improved somewhat in the Great Lakes Basin. For decades farmers have been exhorted to decrease erosion by proper plowing direction on slopes and by allowing natural vegetation areas (buffer strips) near water courses and to apply fertilizers and manures at the best times of the year. The majority of progress has been in the development of o-till" farming. This is a system in which the new crop seeds are planted through the stubble of the last year crop without plowing or tilling. o-till" offers a labour and energy saving that farmers are finding attractive regardless of the implications for decreased erosion. It remains to be seen as techniques are further developed whether the uses of pesticides and herbicides which may be higher with o-till" are consistent with environmental improvement. The major advances have come when farmers have sensed an economic advantage in decreasing non-point pollution. At the same time fields are increasingly underlain with drainage systems that can conduct agricultural chemicals to water courses. Although it is well known that loss of topsoil is a long term threat to agricultural productivity there is little thought given to the long term thus it is fortuitous that concern for aquatic ecosystems has generated additional interest in agricultural practices. An increasing concern is the intensification of industrial style feedlot operations for pigs, cattle, and fowl. These operations with sometimes thousands of animals have caused a further concentration of waste buildup with concerns for water courses and even for groundwater quality. In general, the economic and political systems are not in place to bring about wide scale changes in agricultural practices that would minimize the effect of non-point sources to water from agriculture. Rather than expend vast resources attempting to enforce a myriad of regulations governments have chosen to enforce a smaller number of key regulations and have chosen a long term persuasive approach. Success of this approach awaits the development of attitudes consistent with sustainable ecological/economic hygiene.

Even though the Great Lakes were not grossly polluted on an international scale strong action was required. Large decreases in phosphorus loads are needed to bring about improvements. Computer modeling suggested a 50% decrease was required for Lake Erie. When that action was taken the ambient concentrations decreased accordingly. Similarly, a massive decrease in phosphorus load has been needed in Hamilton Harbour. Our waters in the Province of Ontario seem to need a phosphorus concentration of under 20 μg/L in order to avoid excessive algae populations. Our problematic areas had 40–50 μg P / L and this meant no less than drastic action would bring results. In the case of Hamilton Harbour the phosphorus concentrations were so high that, in the early days of more control, large load decreases did not result in better water quality. This was because the water was completely overloaded and algae were light shaded and unable to grow in proportion to the nutrient concentration. Where there is serious pollution serious action must be taken. To avoid disappointment in pollution control, the ultimate scale of load reductions needed should be accepted and the apparent ineffectiveness of early control efforts should be anticipated.

There is often skepticism that point source nutrient control will have a beneficial effect in relation to all the other sources. In some systems a large portion of the annual load can appear from non-point sources so it may appear, mathematically, that point source control would have a minor effect. Yet, the highly available point source loads occur every day whereas non-point loads are often driven by rain events and may be dominated by soil P at non productive times of year. The timing and availability of sources to algae should be considered. Another consideration is so called internal loading or sediment regeneration. Sometimes high rates of internal loading are used as evidence that reductions in external loads would be ineffective. Internal loads are actually recycling mechanisms. When there is a flux of phosphorus from sediment to water then there can be a net loss from the lake due to flushing. Assuming the sediments represent storage of externally loaded P to begin with then regeneration from sediments should decrease with time if external loads are reduced. Laboratory experiments on sediment regeneration can be misleading because the physics of important water movements over the sediment cannot be duplicated and the experiments cannot show the net sediment water interaction which includes sedimentation as well as regeneration. Thus, the estimates of internal loading may distort the true effect of the lake bottom on the water. Nevertheless, sediment regeneration can slow response to reduced external load but it is the author opinion that in most cases reduction of external load is still justified. The Bay of Quinte, Lake Ontario, for example, has high rates of internal loading and yet this ecosystem has responded well to sewage load reduction (Nicholls, 1999).

5 Summary

- The Great Lakes phosphorus load reduction program was a success resulting in 50% lower phosphorus concentrations and corresponding algal populations in Lakes Erie and Ontario.
- Reduction in P load in the Great Lakes was mainly through reduction of detergent P and P precipitation at sewage plants.
- Strong nutrient control actions are still needed in many restricted areas of intense pollution.
- Non-point source control in agriculture has been mainly through no-till farming and the use of buffer strips near water courses.
- Advances in sewage plant efficiency can be made through objective monitoring and evaluation of operating practices and construction engineering.
- Recovery from intense nutrient pollution requires large load reductions before benefits can be seen.
- Availability of P sources to algae should be considered before deciding on which sources are most important.

- Internal sediment recycling does not represent a new source of phosphorus; depending on the system, recovery may be delayed but is seldom prevented.

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Series of Technologies for Water Environmental Treatment in Caohai,Dianchi,Yunnan Province

Liu Hongliang
Chinese Research Academy of Environmental Sciences,Beijing, China

Absract Caohai, part of Dianchi in Yunnan Province, is heavily polluted by the discharge of urban waste water, lost its water body function, and thus threatened the water source of Kunming City. In order to control water pollution in Caohai, comprehensive series of technologies, such as transformation of urban drainage and treatment system, treatment of main industrial waste water, treatment of area pollution source dredge-up of river silt in Caohai, on-site clear-away technology of pollutants, recovery technology of large aquatic plants, and reasonable management of water resources, are put forward, and short-term plan, mid-term plan and long-term plan for Caohai and Dianchi are formulated. Total investment for these plans is expected to be about 3 billion Yuan RMB.
Key-words Series of technologies for controlling Caohai Sustainable development strategy Comprehensive control program

1 Main Environment Problem and Treatment Method in Caohai of Dianchi

Dianchi as the largest altiplano freshwater lake in china lies in Kunming, Yunnan Province. It include Neihai and Waihai, Neihai another name is Caohai, which is in upriver of Dianchi, nearby Kunming City. The area of Caohai is about 8.15 km^2, occupying 2.7 percent of Dianchi total area. Receiving 45 percent wastewate of total area. Caohai water quality exceed standard of Grade Ⅴ ground water for a long time.

Dianchi, particularly Caohai aged quickly , the main factor is due to human being. Before time we make many mistakes, we tried to take grain as the key link in lake and forest, Lake reclaimation reduce lake area and weaken ability of containing water. Since 1980s , our country economy progressive rapidaly, and accordingly discharge waste water increase quickly , Dianchi is heavily polluted by the discharge of urban waste water, lost its water body function. The main environment problems such as: organic pollution and Eutrophication; endogenesis pollution is prominent; hyacinth grow up crazy; biodiversity species are disappear; morass increase quickly; Caohai is a rothole of total Dianchi .

Contraposing the main environmental problem of Caohai, we must correct our mistakes and persist in sustainable development strategy, take a reasonable management about relatives between economy progressive and protection water resource; Correspond water source and protection; Integrate drainage area control and lake management; Combine endogenesis and exterior pollutants treatment; Link traditional treatment and new biology recovery technology.

2 Proposal of Treatment Caohai Spot Pollution

2.1 Main industrial pollution

Caohai drainage area concentrate 434 enterprises, The main pollution enterprises are smelting, paper making, antibiotic making, printing and dyeing, tannery, pharmacy etc, are about 16 main enterprises, this number is only 0.5% of total enterprises, while they product 80% pollutants of Caohai drainage area total enterprises pollutants.

Therefore we must take perfect method to treat these main pollution enterprises, First, if some industrial wastewater can enter into drainage pipe directly. This is very good; if some industrial wastewater post-treatment can be treated together with municipal wastewater, These enterprises wastewater is pretreated then enter into municipal drainage pipe. To those enterprises whose wastewater post-treatment is not able to enter into municipal drainage pipe, They should treat their waste by themself.

2.2 Proposal of transformation of Kunming municipal drainage and treatment system

Ⅰ. Present drainage and treatment system of Kunming

Now Kunming municipal drainage and treatment system is confluent one. i.e. waste water and raining enter into Dianchi through drainage pipe, and this system threatened the water source of Kunming. There are four systems, include Mingtong river, Zhengcao river,Yunliang river, Yinhan river. The drainage area is 90 km^2, and population is about 1.25 million, total wastewater is 420,000m^3/d, 153 million m^3/a.

There are 18 blocks with raining drainage systems, total area is 4,390hm^2, at last enter into Panlong river, Zhengcao river, Mingtong river, Daguan river, Yunliang river, and Chuanfang river, at last it enter into Dianchi.

Ⅱ. Proposal of transformation of Kunming municipal drainage system

In order to catch wastewater, Lead wastewater to municipal treatment plant, It is necessary to transformation of Kunming municipal drainage system, change confluent drainage system to diffluent system. The new drainage system take up with perfecting branch pipe, main pipe function. New blocks apply diffluent system and old blocks change confluent drainage system to diffluent system. Recovery and reinforce the old pipe which is destroied and lack of preparation.

After four system transformation being finished, perfect urban wastewater system will come into being, at the same time, will built 18 blocks raining drainage system.

2.3 Treatment proposal wastewater course to Caohai

The main tasks of recondition wastewater course are as follows:

⑴Daguan river recondition project.

First, cut wastewater into first municipal wastewater treatment plant of Kunming city. Northland catch wastewater project combine with West industrial area transformation drainage system process. Leading wastewater into Wulong river and Yunliang river, finally enter into the third wastewater plant, which will be built in plan, the total long of catch pipe is 6km. Second, introduce water program is with Panlong river pump station pumping Dianchi water through Panlong river, Yudai river, Xiba river into Daguan river, and purifying Daguan river water. Third, virescence project. Built new planting area and small garden.

⑵Yunliang river recondition project.(brief)

⑶Xinhe recondition project. (brief)

⑷Chuanfang river recondition project. (brief)

Table 1　Investment of recondition wastewater course

Serial number	Title	Content	Investment (million RMB)
1	Yunliang river recondition project	Dredge riverway3km, rebuilt bank 2km, catch wastewater pipe 9.3km, virescence	5
2	Daguan river recondition project	Catch wastewater pipe 6km, built two new pump station , built a new RC brake dam, built new bank 100m, built new introduce water project, virescence project	31
3	Xinhe recondition project. (brief)	Catch wastewater pipe 12.6km, Dredge riverway 3km, transformation bank and virescence project	5
4	Chuanfang river recondition project	Built new bank 1.2km, Dredge riverway	2
Total			43

2.4　Forecast of pollution load development in Caohai system

Ⅰ. Forecast method and foundation

Caohai programming area is separated two drainage systems, and forecast time is short-term (2000 year), mid-term (2010 year) and long-term (2020 year).

Adopt grey system GM(1,1) model as forecast mode.

Ⅱ. Water quality respond analysis of Caohai spot pollution control project proposal

⑴Water quality respond equation

In order to control water pollution and purifying, it is necessary to take some process to treatment spot pollution and make water quality reach up to standard, Water quality respond equation is as follows:

$$C = a\,\mathrm{Win} + d \quad (a=1/Q,\ d= A0Ks/Q,\ Q=KV)$$

in equation:

C—Caohai water quality goal Control value;

Win—Permission pollution load;

$A0$—Lake bottom area;

K—TP—TN comprehensive degradation coefficient, L/d;

Ks—Bottom sludge N, P release speed, mg/(m^2 • d);

Q—Flux;

V—Volume.

⑵The results of water quality respond

According to above equation, input parameters, use 0–1 type mode, the results are showed in table 2–4.

From table 2 to table 4 we can get follows condition:

Table 2 Short-time Water quality respond of Caohai spot pollution control project proposal

Items	Cutdown (t/a)	Percent of cutdown (%)	Water quality respond (mg/L)	Water quality goal Control value (mg/L)
TN	1,372	59.11	4.41	5
TP	189	76.15	0.42	0.5
BOD_5	6,680	85.93	8.13	10
COD_{Cr}	14,621	85.32	9.03	12

Note: the first and the third wastewater treatment plant scale is 350,000m^3/d, secondary treatment, investment 4,100million RMB.

Table 3 Mid-time Water quality respond of Caohai spot pollution control project proposal one

Items	Cutdown (t/a)	Percent of cutdown (%)	Water quality respond (mg/L)	Water quality goal Control value (mg/L)
TN	2671	67.45	4.623	3
TP	302	80.75	0.43	0.3
BOD_5	11 650	87.75	8.61	10
COD_{Cr}	22 437	87.00	9.1	10

Note: the first and the third wastewater treatment plant scale is 410,000m^3/d, investment 1,350million RMB.

Table 4 Mid-time Water quality respond of Caohai spot pollution control project proposal two

Items	Cutdown (t/a)	Percent of cutdown (%)	Water quality respond (mg/L)	Water quality goal Control value (mg/L)
TN	3 087	82.3	2.48	3
TP	344	91.0	0.207	0.3
BOD_5	12 668	96.5	2.17	10
COD_{Cr}	23 531	91.0	4.16	10

Note: the first and the third wastewater treatment plant scale is 410 000m^3/d, Grade tertiary treatment, investment 2 150million RMB.

The first, short-term Caohai spot pollution control project proposal is enough to reduce Caohai pollution speed, and Caohai water quality satisfies standard of Grade Ⅴ ground water.

The second , Mid-time water quality of Caohai spot pollution control project proposal one, in which the first and the third wastewater treatment plant scale is 410 000m^3/d, Grade Ⅱ treatment can not make Caohai water quality satisfies standard of Grade Ⅴ ground water.

The third, Mid-time water quality of Caohai spot pollution control project proposal two, in which the first and the third wastewater treatment plant scale is 410,000m^3/d, Grade Ⅲ treatment can make Caohai water quality satisfies standard of Grade Ⅴ ground water .

In a word, Caohai pollution control project can not only depend on municipal wastewater pant, It is necessary to adopt a comprehensive control program.

3 Caohai Endogenesis Pollution Control Program

Caohai is 2.17m deep, while pollution bottom sludge is above 1.5m, there are a lot of nourishment salt, toxicant, these become the endogenesis pollution of Dianchi.

In order to grasp the deposit regulation of Caohai bottom slude, we collected 47 samples at 2 m deep in upright direction.

These samples are separated three parts, top A, B and C layer is watery bottom sludge, which colors is heavy; Medium D, E and F layer is remainder of Submerged macrophyte; G and H layer is ordinary lake bottom sludge. To find out transverse distributing rule, we make 14 transverse section.

From above information, adopting Simpson law, we can accurately calculate the deep and quantity of dredge up Caohai bottom sludge. To control sludge sand diffuse during dredge up, we should use large flux twist suck ship. The dredge up area is $3.01km^2$, sludge quantity is 36.3 million m^3, dredge deep is about 0.5–1.8m, dredge time is 35.1 months, total investment is 108.73 million RMB. Stack reclaimation earns 205.56 million RMB[2,3].Removing TN ,TP are 28,010t and 63,00t respectively.

4 Using Bioengineering Control Caohai Pollution Technology Program

4.1 The large aquatic plants and biodiversity disappear

In 1950s and 1960s, there are four main aquatic plants in Caohai , Those are emergent macrophyte, Submerged macrophyte and floating plants and have a good biodiversity. In 1970s for lake reclaimation, lake area decrease rapidly; Caohai is heavily polluted by the discharge large wastewater, Floating plants Community Nymphodes peltatum and emergent macrophyte disappear. In 1980s, Community Vallisneria Spiralis and Community Potamogeton malaianus are disappear too. In 1990s there are only Community Eichhornia crassipes, Community Potamogeton pectinatus, Community Floating plants, Community Azolla imbricata and Community Alteranthera philoxeroides.

Hyacinth is the largest biome, distributing area 6 km^2, Covering with 80%. The biomass is $15–20kg/m^2$. Now the floating island is made of hyacinth is very serious.

Potamogeton pectinatus had been in Caohai for a long time and there are Potamogetonaceae such as Potamogeton perfoliatns and Potamogeton malaianus ect. But they were disappeared in 1970s. Potamogeton pectinatus was still existence in East Caohai, However with Hyacinth grew up crazy, In 1988, there are disappear more and more . in 1993 and 1994, some Potamogeton pectinatus were found again,distributing area is 10–20km^2, covering with 40%–50%, The biomass is 1 kg/m^2. This proved that Potamogeton pectinatushave is a good acclimation.

Using Shannon Wienner′ s equation calculate Biodiversity index:

$$H=\sum_{i=1}^{s}(n_i/N)\ln(n_i/N)$$

In equation :H—Biodiversity index;

s—Species Number in community;

n_i—i Species covering percent;

N—all species covering percent.

The results show in table 5–6.

Table 5 Grade of Biodiversity index—*H* and meanings

Grade	*H*	Meanings
Very good	>2.0	Aquatic plants full-fledged, have many variety plant community; species rich and have no human disturb.
good	>1.5	Full-fledged, large area submersed macrophytes, species rich. have some human disturb.
ordinary	>1.0	Have submersed macrophytes, little area, species is poor, have obvious human disturb
Not good	>0.5	Single species in plant community, predominance is obvious ,biomass is high or low, have been disturbed heavily by human being
Bad	<0.5	Have been disturbed heavily by human being, Have no submersed macrophytes, species are single.

Table 6 from 1950s to 1990s Biodiversity index and evaluate

Time	*H*	Evaluate
1950s	2.704	Very good
1960s	2.36	Very good
1970s	1.98	Good
1980s	1.02	Ordinary
1990s	0.29	Bad

From table 5–6 we can get conclusion: first, when organism load increase, Dianchi Eutrophication is heavily, alga density increase, transparence decrease ,induce water bottom have little illumination and submersed macrophytes disappear. Second, in order to recovery submersed macrophytes we must increase transpare of Dianchi.

4.2 Caohai biogeocenose control program

From 1996 to 2000, series of control program have been carried out, Dinchi and Caohai pollution are drew up, about one of the third aquatic plants are recovery. Along lake bank 1.65m deep, 100–400m width area appear submersed macrophytes which is mainly Potamogeton pectinatus, about covering 10% area of Caohai.

From 2001 to 2010, to recovery environment Dianchi and Caohai, ensure water resource and biology source sustainable development; carrying out separate waste and pure; spot pollution water drainage through municipal treatment plants, After treating waste water into lake, the transparence is above 0.8m, T-P<0.05, T-N<1mg/L, DO>7mg/L, phytoplankton < 50 million. The total ecosystem is obvious improve .Caohai, particularly in Waihai aquatic plants community , there are maybe some sensitivity species appear. submersed macrophytes are above 15 kinds of species; Neihai also can be recovery through biogeolenose; This will bring zoology quite quantity of benefit. Submersed macrophytes resist pollution abilty: Potamogeton pectinatus > Hydrilla verticillata >Ceratophyllum demersum > Myriophyllum spicatum> Vallisneria spiralis > Elodea Nuttallii > Chara Contraria. On-site test indicate that nine species Submersed macrophytes can be living in Duanqiao, Mid-Caohai, while in other places these species will be rot, because water quality and transparence is different[4].

5 Research New Technology to Purifying Lake

Using American A.M company microbe patent production purifying lake, this was an attempt to extend this technology.

5.1 Choose test site

Selective water is about 1km away from Caohai, it close in inner lake. The water in this lake was opaque, green and have many “water blooms”, Indicate The lake is heavily eutrophication. It is very resemble with Caohai.

During experiments, through surface change of test water, we can get conclusion that these microbe technologies are useful. At beginning, although it is winter, the lake is full-filled water blooms in northeast and northwest corner, After six nonths, the lake had not any water blooms and the color of water was buff. Otherwise control water is still green.

5.2 Compare experiment results with other technology

In 1992, New York city center park adopted this technology to purify five lake. Among the five lake ,center park 59 street lake is heavily polluted .Comparing this lake test to our test, showing in table 7.

Table 7 Comparing this lake test results to our test

Items		Transparency(cm)	Temperature(℃)	DO(mg/L)	pH	NH_4–N (mg/L)	BOD_5 (mg/L)	Remark
U.S.A	Initial	31	24	8.7	6.9	0.6	8.5	
	test	51	22	8.7	6.8	0.2	3.6	
Japan	Initial	26	10	8.8	8.1	2.75	25.74	
	test	53	24	8.8	1.03	1.03	1104	

Note: “1200”, “1000” and 1001 reflect three microbe fungiform.

From table 7 we can get center park 59 street lake increased from 31 to 45 and our test water transparence our test initial from 26 to 53, But our test initial NH_4–N, BOD are higher than

America. So we can say our technology is up to international level .

6 Forecast Effects of Xiyuan Tunnel Project

6.1 Dianchi control flood and waste water recycle project.

The project carried out by two stages, One stage is separate water area project; Xiyuan tunnel project, Separate control program; Second stage include Daqing river catch waste water program. Maliao river reservoir project; Kungan water supply project.

6.2 The main task of project

First, separate Dianchi to Waihai and Neihai

Second, Floodway and flood out. Building a new tunnel in Caohai, let the flood from Zhongtan brake into Caohai; and the water flow out through Xiyuan tunnel, Lighten the load of Haikou and introduce municipal wastewater into Caohai. The waste water in Caohai let out from Xiyuan tunnel.

Third, the water from Xiyuan tunnel flow through Taiping brake, Separate one flow into Taiping tunnel and into Maliao river reservoir Ⅰ and reservoir Ⅱ.

Maliao river reservoir Ⅰ and reservoir Ⅱ preserve the water from Taiping tunnel, and supply water for Kungang industrial .It also supply water for Anning area industrial agriculture. Maliao river reservoir Ⅲ preserve clear flow, supply drink water for Anning area.

If the tunnel project is carried out, it will be obvious comprehensive benefit to control Dianchi environment pollution, exploit and use Dianchi water resource, prevent and control flood. The tunnel drainage has little effect to backward position water quality. The project is controlled by optimizing method, its water quality can reach up to apply for backward position drinking, and it not effect aquatic biogeocenose.

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Towards Development of an Effective Management Strategy for Lake Eutrophication

Takehiro Nakamura
United Nations Environment Programme, Nairobi, Kenya

Abstract The concept of sustainable development entails economic development balanced with human and ecosystem health on Earth. Based on the concept, establishment of a lake eutrophication management strategy requires an integrated basin approach, involving relevant sectors and stakeholders within a lake basin. In this process, the issues that require particular attention include land and water interaction, non-point sources of nutrients, invasive aquatic weeds, socio-economic and cultural implications, legislative and institutional arrangements and public participation. In applying this concept, a complicated system of interactions of environmental and socio-economic factors in the Lake Erhai basin, China, was modeled to serve as a basis for establishing a lake management strategy.

Key-words Management strategy Integrated basin approach Non-point sources of nutrients Lake Erhai

1 Introduction

The United Nations Conference on Environment and Development in 1992 in Rio de Janeiro endorsed the concept of sustainable development, which should form a basis for future economic development balanced with human and ecosystem health on Earth. In order to ensure harmonization of these elements, sectors that did not have dialogues before now need to ensure co-ordination and co-operation. Therefore, sustainable development encompasses maintaining the environmental quality, and achieving socio-economic development, and ensuring the best institutional arrangements. In applying the concept of sustainable development to freshwater resources and environment management, integrated water resources management aims at achieving maximum benefits of human and ecosystems by balancing water resources exploitation and economic development of basins, protection of aquatic environment, and institutional arrangements for co-operation and co-ordination among the water, environment, health, agriculture, industry and other relevant sectors at various levels.

It has recently been more recognized that management of quality and quantity of freshwater resources and health of freshwater environment cannot be achieved without addressing natural and human activities that have impacts on quality and quantity of freshwater. This means that land-based activities in the hydrological, geochemical and ecological cycles within basins influence availability and quality of freshwater. In this way, basin management for the ultimate purpose of controlling quality and quantity of freshwater resources needs addressing natural and human activities within target basins. An integrated basin management is intended to manage the various factors in the basins in order to achieve multiple objectives for resource use and protection of the aquatic environment. It is also an approach, which essentially takes a cross-sectoral and interdisciplinary approach to achieve institutional co-ordination and co-operation.

2 Lake Eutrophication Management Strategy

Lake eutrophication was identified as one of the six major threats to lake environment (the rest are siltation, water level decline, toxic contamination, acidification and disruption of lake ecosystems) by the United Nations Environment Programme (UNEP)/International Lake Environment Committee (ILEC) project on the Survey of the State of the World Lakes completed in 1997. The UNEP/ILEC Survey also looked into the trophic status of 215 lakes all over the world, and the percentage of lakes and reservoirs with eutrophication problems by region is as follows (UNEP, 1994): Asia and the Pacific: 54%; Europe: 53%; Africa: 28%; North America: 48%; and Latin America: 41%.

For the purpose of control and management of lake eutrophication, management targets are set on control of excessive nutrient flow into target lakes. These excessive nutrients originate from the lake basins, caused by natural and human activities. It is, therefore, necessary to understand the system of sources, transport, input and in-lake processes in order to decide on the strategy for control of eutrophication. Such an analysis will also contribute to assessing environmental and socio-economic impacts of eutrophication and of measures to address eutrophication. Different types of interventions can be expected at the varying parts of this process. In some cases, addressing sources of nutrients may be cost-effective and technically feasible, and in other cases, in-lake intervention may be more cost effective. Further, even though the sources and nutrient loads are identified and quantified, in many cases, it is not easy to directly address those sources, because the relevant human productive activities have direct impacts on socio-economic conditions of people living in a basin. Unfortunately, socio-economic and environmental implications of proposed measures to address sources of excessive nutrients can not be readily estimated.

3 Overview of Management Issues

3.1 Land and Water Interaction and Non-Point Sources of Nutrients

In taking a basin approach, it is easily understood that land use and land-based activities are closely related to the changes in water quality and availability. For instance, agricultural practices determine how much fertilizer the agricultural sector uses, and further, the way such fertilizer may enter into water bodies. Therefore, land management activities are a key to addressing the sources of nutrient input to the basin’s hydrological cycle. Traditional river basin management focused on water flow, run-off and water quality, and land use and land-based activities were not within its main focus. This is partly because different sectors deal with such land issues, and co-ordination among these sectors was not fully incorporated into the management, and partly because land use management normally requires detailed planning and investment.

Excessive nutrients originate from point or non-point sources. Efforts have been made, in both developed and developing countries, to address point sources of nutrients in relation to lake eutrophication control. Despite these efforts, degradation of aquatic environment continues to be seen, and more attention has now been directed to non-point sources of pollution, such as agricultural run-off, and storm water drainage. In principle, identification of and addressing non-point sources of pollutants is not technically readily available or economically feasible, particularly in developing countries (Thornton, et al., 1999). Further, the non-point sources of pollution originate from a wide range of human activities, and its social and economic impacts are not comparable with that of point-source pollution.

3.2 Invasive Aquatic Weeds

Thick mattresses of aquatic invasive plants, such as water hyacinth, *Eichhornia crassipes*, and *Salvenia molesta*, can grow very rapidly. There was an indication of scientific literature that eutrophic waters may provide better conditions for proliferation of such aquatic weeds, although aquatic weeds can adapt themselves to various nutrient conditions. Such aquatic weed proliferation impacts on fishery (difficult access to fish landing site, destruction of fish nursery ground, etc.), water supply (clogging of water intake points), hydropower generation (clogging of dam waterways), irrigation (clogging of intake points), and navigation (difficult access to port facility). Further, rapid proliferation of one species may change the ecological structure. Water hyacinth is composed of 95% water and 5% dry matter, approximately half of which is silica. There are several attempts to use water hyacinth for biogas production, pig feed, production of paper and furniture, etc. For urgent and severe impacts of water hyacinth, there are proposals, depending on urgency and potential environmental impacts, for (i) manual and mechanical removal; (ii) chemical removal (herbicides); and (iii) biological removal (weevils).

3.3 Socio-Economic and Cultural Implications of Eutrophication

Wastewater from human life may contribute greatly to the progress in eutrophication. In developed world, a large-scale wastewater treatment facility has been developed, where use of human waste for agricultural purposes can not be culturally accepted. In East Asia, there is a tradition to use human waste for agricultural fields, which not only contributes to increasing crop yield, but also curves use of chemical fertilizer. Of course, there is a negative aspect of use of human waste, particularly one on public health.

Further, eutrophication of lakes gives public health problems such as increased mosquitoes and water borne diseases. In addition, eutrophic lakes may damage natural and cultural landscape. Some lakes in China are considered as cultural and historical spots (e.g., Xihu, Lake Dianchi, Erhai, etc.), and algal bloom may lead to decreased tourism value for these areas.

When eutrophication is progressive, productive capacity of water, or economic value of water, is reduced. Economic activities, such as agriculture, which are related to causes of eutrophication (such as use of fertilizer), do not necessarily internalize environmental costs (in this case, reduced value of water by eutrophication). In case the one who discharges excessive nutrients is different from the one who suffers from eutrophication, economic gaps (between the one who gains and is related to root causes and the other who has to pay for reduced value of water) needs to be filled by the one who contributes to the causes. However, in the absence of clear understanding of causes and effects, such economic issues may not be easily solved.

Direct economic impacts of eutrophication appear also in the form of reduced number of tourists, high cost of water treatment, high cost of public health, cost of lake ecosystem restoration, costs for introduction of control technologies, etc. It is reported that in Sao Paulo, Brazil, the price of properties was devaluated by 50% as a results of algal bloom and macrophyte growth, and resulting loss of recreational capacity (UNEP, 1999). Interventions to control eutrophication also have economic impacts on specific sectors. For instance, treatment of wastewater needs an initial capital investment. To reduce nutrients from agricultural runoff, use of fertilizer has to be restricted, and this may result in other agricultural practices or lower crop yield, both of which have direct economic impacts. In establishing an eutrophication control strategy, there are several potential economic instruments that can be used, including: effluent taxes/charges, tradable discharge permits, financial aids and subsidies, reimbursable deposits, and compliance incentives.

3.4 Legislative and Institutional Arrangements and Public Participation

Addressing eutrophication needs involvement of various sectors, such as water, agriculture, fishery, environment, tourism, etc. It also requires political and economic incentives at various levels (central and local governments, private company and the general public). In order to maximize management efforts, a good co-ordination mechanism also needs to be established among relevant sectors. An integrated basin approach would also enhance co-ordination of management activities to address eutrophication. Also necessary is appropriate legislation. Lake basin commissions/authorities/organizations could work as responsible bodies that can co-ordinate activities by various sectors. Relevant legislation may accompany such a basin-level organization/commission. For example, for the Murray-Darling River basin in Australia, based on the Murray Darling Waters Agreement (1917) the River Murray Commission was established. This evolved into the Murray-Darling Basin Commission, involving several States and central government. In this process, its mandate was broadened from navigation and water sharing to include water quality issues. Further, the Murray-Darling Basin Ministerial Council was formed, under the Murray-Darling Basin Agreement (1992), to address a wide range of issues for co-ordination. The Murray-Darling Basin Ministerial Council adopted, among others, the Algal Management Strategy (Ritchie and James, 1997).

For eutrophication management, public participation is an important element, because the causes of eutrophication is closely linked with the citizen’s life (such as wastewater treatment, use of detergent, etc.) and its impacts are directly on their life (such as quality of drinking water).

Restricted use of phosphate detergents needs to be promoted among the citizens, and the causal relationship between the use of phosphate detergents and degradation of water quality by eutrophication should be understood. It is also noted that private company involvement is an essential and indispensable factor for eutrophication control. Many of water related services are privatized in many countries nowadays, and further a wide range of private companies are involved in direct and indirect causes and impacts of eutrophication on a basin scale.

4 Environmental Planning for Lake Erhai Basin

UNEP and the United Nations Development Programme (UNDP) initiated their assistance to the Government of China in 1994 to address environmental issues relevant to Lake Erhai and its basin, Yunnan Province. In the process of implementation of the project by both organizations, in 1996, the nutrient values indicated historical extremes in the lake, and algal bloom was observed. Considering the significance of the lake from tourism and water use perspectives, water quality control in the lake was given the main focus of the UNEP/UNDP assistance. UNEP's assistance was centred on integrated environmental planning of the basin, assessment of environmental impacts of tourists, and transfer of environmental technologies.

Under the integrated environmental planning of the basin, which was carried out in co-operation with the University of Regina, Canada, analysis of the environmental status of the basin was carried out, and based on the analysis, a model of interactions among various sectors in the basin was developed. Such a model study included scenario studies and served as a basis for developing a lake water control strategy. A schematic illustration of interactive system within the basin was shown in Figure 1. Using the parameters in Figure 1, numerical models were developed for examining future projections of the lake basin development and its environmental impacts. Four scenarios were examined for future projections of the economic development and its environmental impacts, namely, (i) business as usual scenario, (ii) industrial development scenario; (iii) industrial effluent control scenario; and (iv) restricted in-lake net-cage fish culture scenario.

The major findings of the model study were as follows (UNEP, 1997):

⑴The water quality control is given the highest priority in the management objectives. The economic development should not be based on the cost of lake water degradation.

⑵Agriculture is a traditional activity and one-fifth of the total economic return in the basin comes from agricultural activities. The majority of the population is farmers. At the time of the study, nitrogen and phosphorus input to the lake from the agricultural sector composed of approximately 66% and 57%, respectively, of the total loads in the basin. Although some of the non-point sources of agricultural-origin nutrients can be treated by engineering measures, agricultural activity growth and its related pollution should not fluctuate in time even in comparison with that of tourism or other industry.

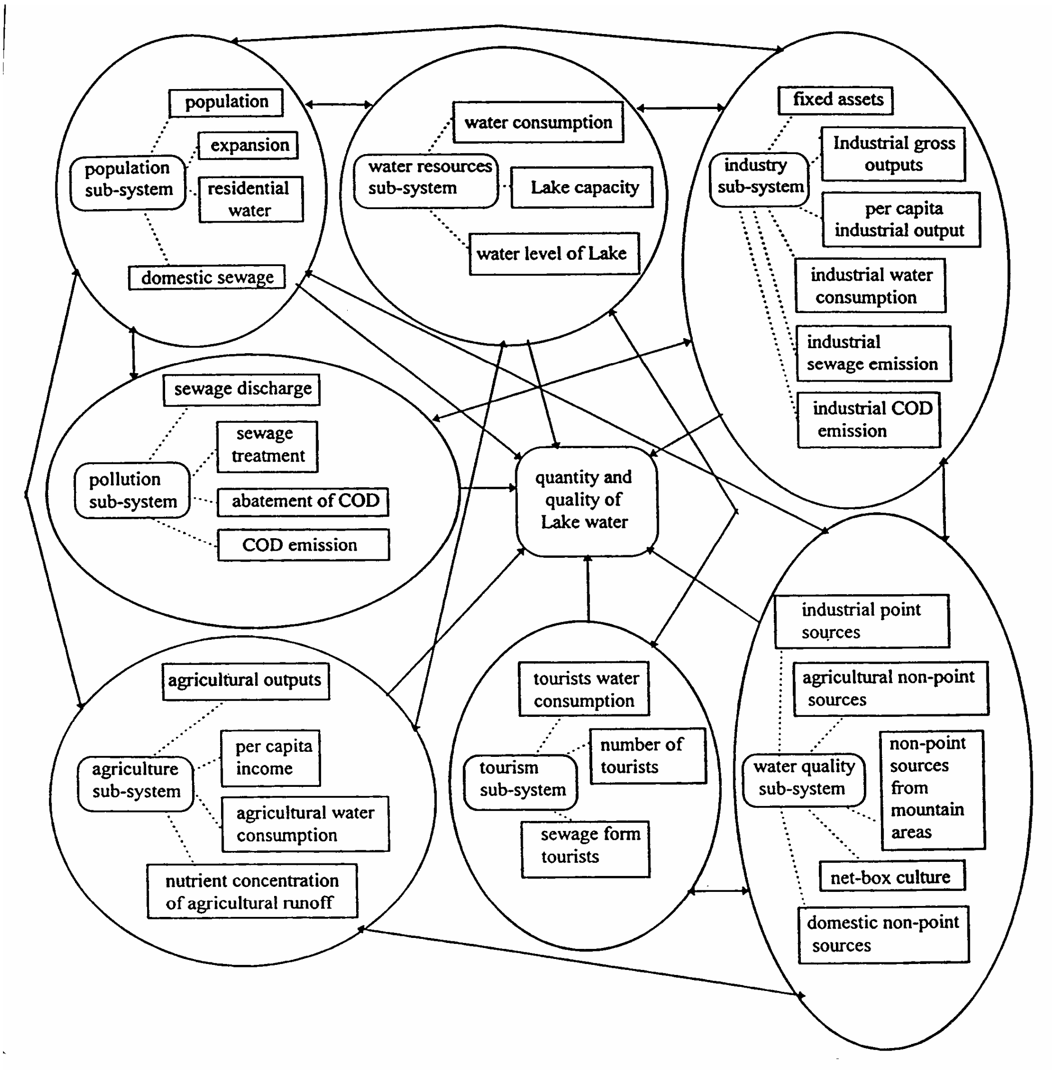

Fig. 1 A model for interactions among the components in the Lake Erhai basin (UNEP, 1997)

(3)Cigarette and food processing industries would be promoted from both pollution reduction and economic development perspectives. For pulp/paper, chemical fibre, leather, textile and cement industries, careful review for their operation and further development may be required.

(4)Necessary measures should be taken to address in-lake net-cage fish culture.

5 Disclaimer

The views expressed in this article do not necessarily reflect those of the United Nations Environment Programme.

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A Rapid Efficiency-method for Algal Control

Kojima S.

Nihon Suido Consultants Co., LTD

Abstract Rapid efficiency-methods for algal control are proposed. Circulation of lake water by intermittent aeration is recommended for Deep Lakes (average depth more than 10meters); Partial shading method is recommended for shallow lakes (average depth less than 5meters in dry season); For middle depth lakes (Average depth 105m in dry season) both aeration and partial shading will be neccessary.

Key-words Eutroplication control, algal bloom control, Light control, Aeration circulation, Partial shading

1 Introduction

At present, the main worldwide subject for eutrophication is how to reduce nitrogen (N) and phosphorus (P). It is well known that their removal is very difficult and in fact, there is almost no lake that is restored by removal method as well.

In any way, it is without saying that removal of N and P is a mean of algal control but not final target, because there is no toxicity at the nutrient's concentrations level in lakes and reservoirs.

Therefore, it is not necessary to reduce N and P, if it is possible to control the algal production, by other method.

The sunlight is a fundamental element as well as nutrients for the growth of algae. If sunlight can be appropriately controlled, algal bloom could be disappeared, which results in solving the influence of eutrophications.

Lecturer proposes two different methods, one for shallow water lakes and the other for that of deep water, as a measure for the eutrophication using a sunlight shading method.

2 Aeration and Circulation for Deep Lake

2.1 Principle

Artificial circulation of the lake water by air-lift tube can control, not only growth of algae especially blue-green algae, but also improve quality of bottom water. Further, this can inhibit elution of P.

These effects can be explained that inhibition of algae-growth is attained by transportation of algae from light surface layer to dark bottom layer, by the lake water circulation.

Therefore, if artificial lake water circulation technique is used, algae can not grow even if sufficient quantity of N and P exists in the lake water.

2.2 Aerated circulation of lake water by air-lift tube

⑴Structure of air-lift tube

The structure of air-lift tube is shown in Fig. 2. It is a tubular apparatus having a float cell in the upper part and an air chamber in the lower part or the bottom part, and can stand vertically in water by connecting with weight at bottom end.

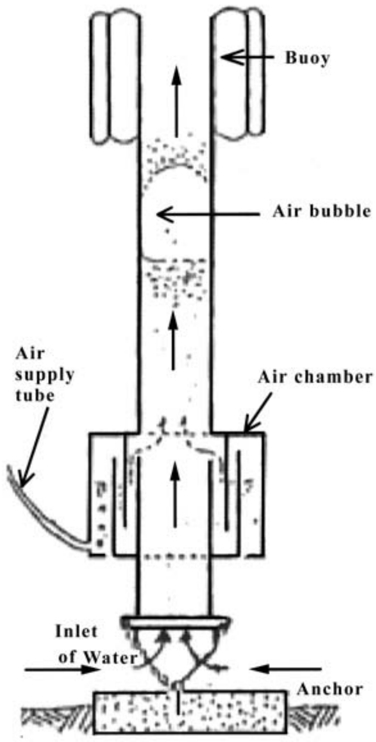

Fig. 2 Cross section of Intermittent Airator

The special device in this apparatus is the air chamber. An inverted siphon installed in this chamber makes it possible to spout air out which continuously brow into this chamber.

This apparatus varied from 300 to 500mm in diameter and 1–30m in length for proportion to water depth. Special tube which have 1–2m diameter also produced for using in large lakes. Generally, these are made of FRP(fiber reinforced plastics).

⑵Mechanism of air-lift tube

Air-lift tube functions as presented in the following process. First, the air sent from an air-compressor mounted on the land accumulates in the air chamber. When the air reaches the bottom end of the inverted siphon, the air in the chamber is siphoned and spouts into the tube so rise in the tube as a bubble like a cannonball.

Then, water is pushed up through the tube like an air gun, and discharged from upper end. Actually, the bubble left from the tube expands like a shape of doughnut by degree and rises to surface of the water together with the water from the tube end and around the course.

Like this, rising bottom water absorbs oxygen by mixing with surface water containing much oxygen and simultaneously becomes lighter due to raised temperature.

Therefore, the water scatters to level direction because it can not return to the bottom layer. On the other hand, the new water from bottom layer flows into the tube and makes rising stream pursuing the bubble.

The bubble erupts at 10–20 seconds interval, so the rising-mixing-scattering of bottom water goes on repeatedly; and the water is circulated and all layer is mixed at last (Fig.1 (b)).

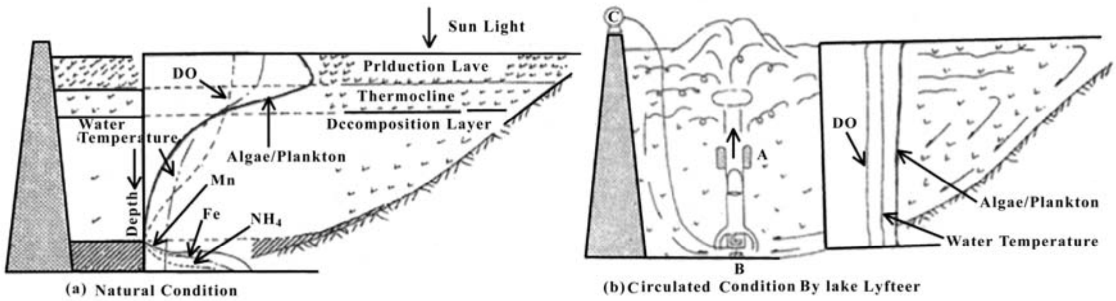

Fig.1 Distribution of lake water quality in summer

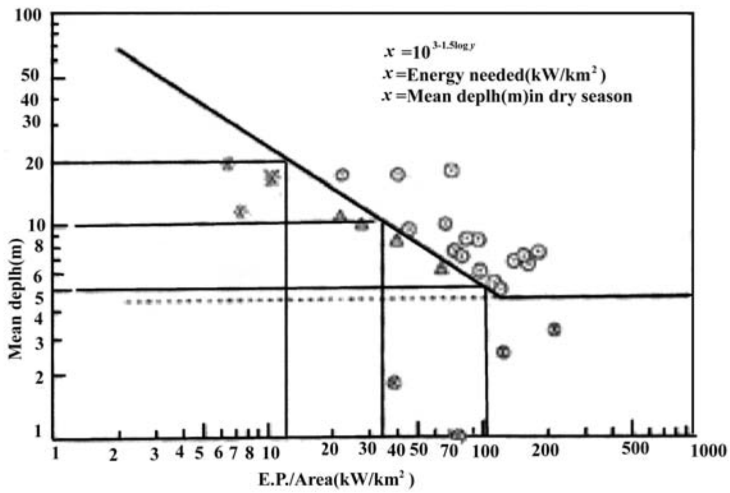

Fig.3 Relationsship between mean depth and energy needed

⑶Calculation method for required energy

Energy (electric power) required for aeration for circulation of the lake water can be estimated by following equation.

$$x = 10^{3.03 - 1.47 \log y}$$

Where, x—the electric power per surface (kW/km^2), and

y—the mean depth (m).

However, these values are obtained from many actual application data.

2.3 Effect and actual results of artificial lake water circulation

(1)Inhibition of algal growth

By circulating the lake water using air-lift tube, phytoplankton decreases rapidly and its species changes from blue-green algae to green algae or diatom.

(2)Removal and prevention of odor

The worst damage of water supply caused by eutrophication is odor trouble, especially mold odor. However, it has been proven that circulation of water in an odorized reservoir by using the air-lift tube can deodorize in short term.

(3)Quality improvement of bottom layer water

Deterioration of bottom layer water quality is due to lack of oxygen, so circulation of lake water can improve the bottom layer water quality by supplying sufficient oxygen to bottom layer. Namely, iron, manganese, ammonia, hydrogen sulfid etc. in the bottom layer water disappears perfectly.

(4)Control of P elution

P in bottom mud can not elude, if sufficient quantity of oxygen exists in the bottom of the lake. That is, ressolution of P from bottom mud is prevented, so the lake becomes to play a role like a P-collecting system.

2.4 Actual results of installation and summary

Installed dam-lakes and reservoirs reaches over 100 points in total in Japan, and their targets are inhibition of growth of blue-green algae causing mold odor and improvement of bottom water quality.

As summary of air-circulation system installation, it is pointed out that the improvement of bottom water quality has succeed in all cases, if sufficient performance was made by the air-lift tube together with energy.

As for inhibition of algae and removal of mold odor, energy is not the most important factor but also water depth is important, as shown in the following:

(1)In case of over 10m mean water depth

Always good results can be obtained. Mold odor and rapid growth of algae are prevented together.

(2)In case of 5–10m mean water depth

Growth of blue-green algae and mold odor can be prevented, but growth of green algae and diatom can not. Especially, growth of diatom becomes remarkably.

(3)In case of under 5m mean water depth

The results is bad. Mold odor and growth of algae can not be prevented almost. Therefore, it can be said this technique is not applicable to lake under 5-meter mean depth.

3 Algal Control of Shallow Lake

It is very difficult to control algae in shallow lakes, as it is widely known.

In this occasion, I would like to recommend the " Partial shading of lake surface", especially for lakes which average depth is less than 5m.

3.1 Principle

It is generally known that to control algal bloom in shallow lake is impossible by "Aeration Circulation Method," because sunlight can reach almost to the bottom, and remain very little dark area. Then, make a dark place by shading a part of lake surface, and let water go in and out under the dark place, which is made by the cover plates. We had corroborating tests on the shading method, and obtained following results.

3.2 Corroborating test

An experimental test for the algal control, by applying partial shading, was carried out in two years 1998 and 1999, during the time spring to fall, at farm ponds that belong to the Water Resources Department Corporation.

The farm ponds are reservoir for irrigation, and made of concrete each with a width of 25–30m, and the length of 35–55m with the maximum depth of 3.3m.

Algae bloom in water is annually formed in these farm ponds, resulting in various troubles.

The experiment of sunlight shading was carried out using two ponds in 1998 and three ponds in 1999, respectively, comparing the control effects for one pond with other ponds. Shading ratio was adjusted into 60% and 50% in 1998; 50% and 30% in 1999, respectively.

In order to shade-out the sunlight penetration, floating plastic boards (20×20cm) were installed in a flame (3×3m) and placed on the water surface for the designed area. Floating stick boards (1×3m) were also used.

In 1998, the proliferated algal bloom was faded out for about one month with the above experiment, and COD was reduced by 50%. It was possible to see the bottom of the pond.

In 1999, the sunlight penetration was controlled with shades by 50% and 30%, respectively in the two ponds. These two ponds had no appearance of the algal bloom, in this experiment.

While, in the pond with no shading, the algal bloom vastly occurred as usual-way with the appearance of scum on the water surface, as shown in Figure 4 (Ref. OHP).

Moreover, the species of algae changed from cyanobacteria into diatom. This phenomenon presents specific advantage for water supply, because there is no fear of the occurrence of strong toxic microcystins and odor in the future.

3.3 Mechanism of water bloom-control

From the above results, some questions were raised; the first question is that why the water bloom, including other light area (L. A.), has also reduced by a partial shading?

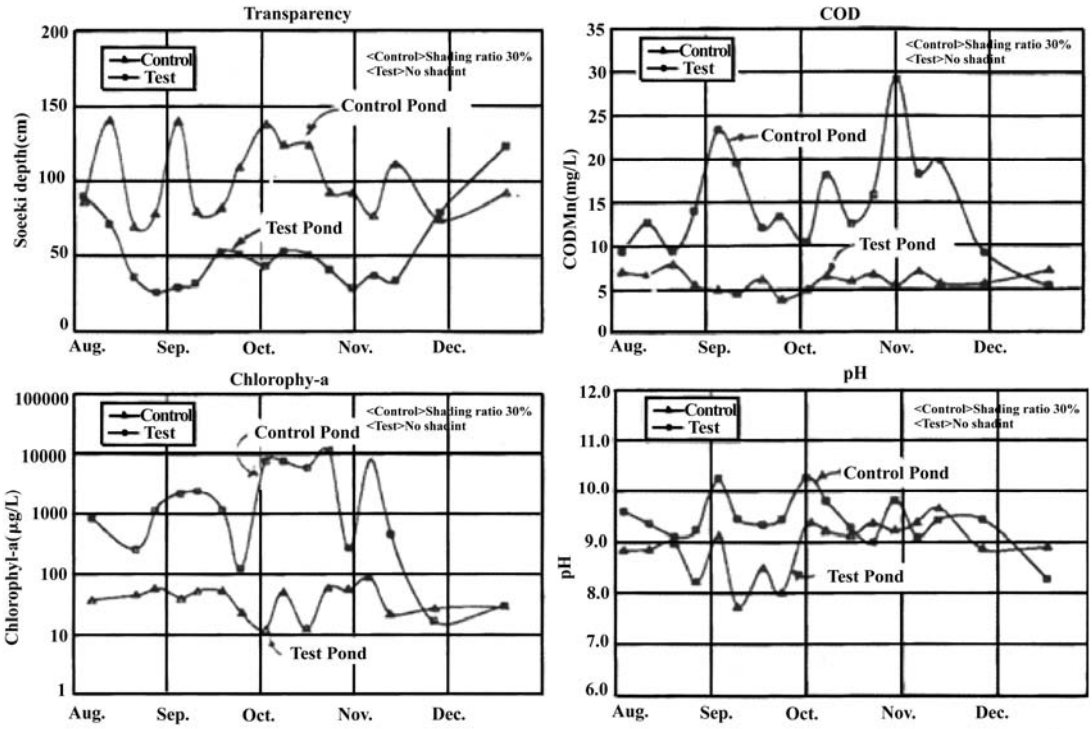

Fig. 4　Results of shaded by 30% of surface and not shaded pond

As for the above reason, it is considered that water in the lake has circulated evenly both in L. A. and dark area (D. A.).

Water in the two water areas are mixed with circulation, which depends on surface drift owing to wind blow and density current, based on temperature-difference due to solar radiation and heat-release. This activity resulted in equal water quality all over the pond water.

The second question is the reason why algae in L. A. do not keep on growth with continuous penetration of the sunlight.

For this question, the growth rate must be one-half to two-thirds of no-shading pond, if all over the water is equalized with circulation as one half to two-thirds of the sun-light energy is continuously given to the L. A.

The last question is that how to maintain the less bio-mass in L. A.

For this inquiry, it can be explained only by the following experiment made by the late Prof. Ichimura of Tsukuba Univ.

Ichimura stored the sample of surface water from Japanese typical eutrophic lake, Teganuma under various sunlight intensity during 1 to 5 days, after that, each sample was illuminated at various intensity and the photosynthetic production was measured (Fig.5).

The darker the stored environment, the longer the stored, when it is put back to a light place photosynthetic ability becomes lower. He clarified the fact described above. In accordance with the theory, algae gradually reduce photosynthetic activity owing to the repeated inflow of the lake water into D. A.

Lecturer names this phenomenon as "shading career effect."

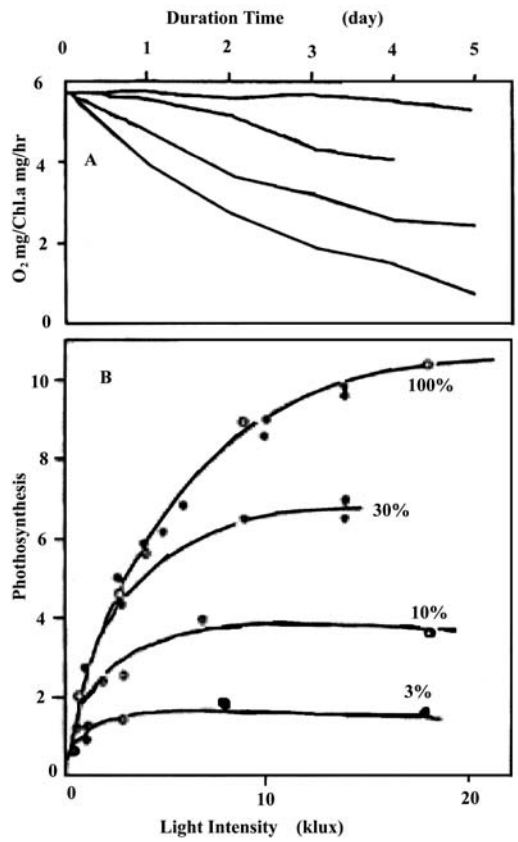

Fig. 5 Photosynthesis pattern of natural photoplankton relating light intencity

A Photosynthesis pattern of algae preserved under various light intencity

B Photosynthesis pattern of algae preserved under various light intencity curve after 4 days preserved

4 Application of Algae Control-method Using Shading Effect

As mentioned above, water bloom can be reduced and faded out all over the water area with partial shading. However, in order to apply this as a practical technology the development of calculation-method for shading area is considered necessary to remain and reserve a suitable biomass of algae. Since, algae play an important role as an oxygen producer but also for the support of ecosystem, as a primary producer.

The complete destruction of algae induce finally complete death of fish, as well as anaerobic condition in lake water. The most important factor for determination of shading ratio is the growth rate of algae, because all water bloom cannot be reduced in the least, even if the bloom in D.A. perfectly faded out. D. A. is supported by two-fold growth in L.A. during the growth-suppression in D.A.

To suppress the increase of algae, it is necessary to meet the following equation.

Rate of shading effect = $\{A/(A+B)\}\times 100$

A: Shading period (day);

B: Two-fold increase period for algae (day).

The two-fold increase period means that mixture of culture-system under natural condition.

In reference with the correlation between shading period and reduction rate of production by Ichimura, the following general equation is obtained.

$$y= 85-52\log(x)$$

Where, y—required shading rate (%);

x—two-fold increase period of algae (d).

Figure 6 shows the correlation of each residual photosynthetic production. In case of application, the following articles should be taken into consideration differing in the lake water.

①Residual ratio of about 20% had better to be used when you would like to reduce residual algae as in water source reservoir as possible.

②Reversibly, 40%–60%-residual ratio will be better to be utilized for fisheries required maintaining the primary production to some extent.

Finally, a part of the area (20%–30%) means very large in a big lake. In this case, a combination of solar generator is proposed as shown in Figure 6.

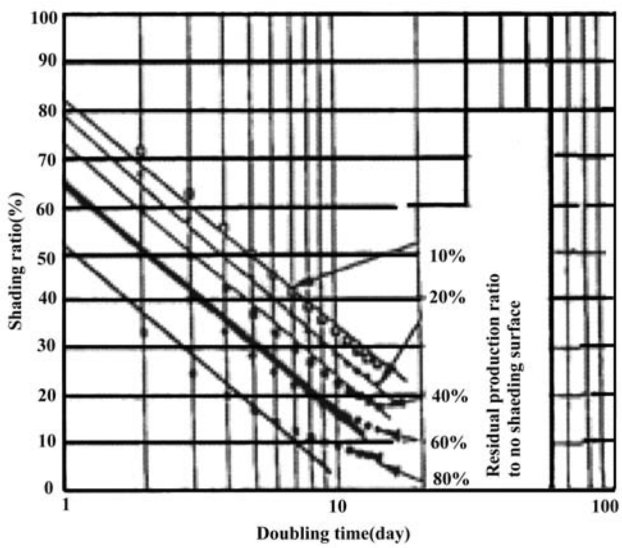

Fig. 6 Shading ratio determing map from doubling time and residual production of algae

Thus, algal control consistent with electric generator can be called that “killing two birds with one stone.”

Eutrophication Control Technology for Lakes in China

Jin Xiangcan Hu Xiaozhen

Chinese Research Academy of Environmental Sciences, Beijing, China

Abstract Based on the analysis of present state and trend of eutrophication of lakes in China, this article concludes that lakes throughout the country are commonly undergoing the process of eutrophication: most of urban lakes are now facing hypertrophication, many medium-sized lakes are of eutrophic state with some lakes even approaching to hypertrophic level, and the five biggest freshwater lakes, especially Lake Caohu and Lake Taihu are already in the state of eutrophication. According to domestic and abroad experiences and successful demonstrations in eutrophication and pollution treatment, the article puts forward the theory of combining source control with ecological restoration for guidance for eutrophication control of lakes in China. At the end of the article eutrophication countermeasures adaptive to Chinese lakes are also discussed.

Key-words Lake Eutrophication Control Countermeasure

China is a country boasting of many lakes, with a total freshwater capacity of $6{,}380\times10^8 m^3$, forming one of the most important freshwater resources in the country. But at present eutrophication has been the most important environmental problems in many lakes and thus exert a tremendous influence on sustainable development of society and economy in lake regions.

1 Present State of Eutrophication of Lakes

1.1 Present State of Eutrophication

Owing to the fact that people have not realized the frailty of the lake ecosystem and lack of environmental awareness, human activities such as land reclaimation and destruction of vegetation around lakes, discharge of large quantities of industrial and agricultural waste water into lakes, and irrational development and utilization of natural resources of lakes, and so on have greatly affected the environment of lakes, which now face many environmental problems. And lakes throughout the country are commonly undergoing the process of eutrophication. As a result, the cycling of the ecosystem of many lakes is damaged, causing great losses to production and people’s life in lake regions. Therefore, eutrophication of lakes has become an important environmental problems in China presently.

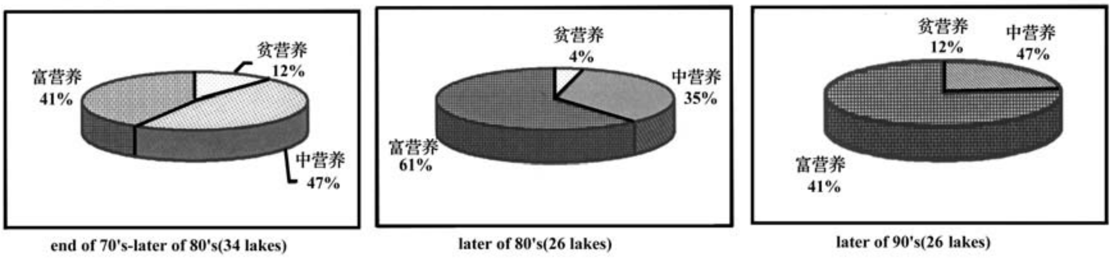

Fig. 1 Trend for Eutrophicatoin Change of Main Lakes in China

1.2 Distribution of Eutrophication

Investigation reveals that many lakes are facing serious eutrophication with extremely high concentration of TN、TP、and Chla and low SD in water bodies(See Table1). Lots of medium-sized lakes are already of the eutrophic state with TN and TP approaching or exceeding the eutrophication transition concentration and some waters even reaching hypertrophic level (Lake Dianchi and Lake Erhai). The five biggest freshwater lakes of China have been generally facing eutrophication with high nutrients in the waters, for example, concentration of TN is above 10 times higher. Now Lake Taihu and Lake Caohu are already in the eutrophic state, with some waters even approaching to hypereutrophic level. And the other three lakes may also entering into eutrophication in the condition of higher nutrient load (See Table1) .

Table 1 Trophic State of Main Medium-sized Lakes in China (Unit: mg/L)

Lake Name	T-P	D-P	DO	Chl-a	SD*	T-N
Outer-lake of Dianchi L.	0.097	0.008	7.22	23.75	0.68	1.20
Erhai L.	0.050		6.10		1.0	0.56
Bositeng L.	0.018	0.007	7.47	4.02	1.50	0.92
Yuqiao R.	0.020	0.001	10.78	6.07	2.60	1.20
Wuliangsuhai L.	0.067	0.045	6.43	4.45	0.70	1.87
Gaozhou R.	0.025	0.005	7.91	0.91	1.90	0.40
Gucheng L.	0.055	0.005	9.59	3.32	0.34	1.70
Dianshan L.	0.088	0.044	8.97	5.98	0.53	1.90
Hulun L.	0.140	0.056	9.56	5.95	0.64	1.90
Qionghai L.	0.140	0.026	6.67	0.67	2.10	1.30
Nansi L.	0.210	0.021	7.37	4.27	0.56	3.40
Jingbo L.	0.400	0.130	9.45	3.62	1.80	1.00
Baiyangdian L.	0.082		11.68			2.30
Qiandao L.	0.050		8.05		5.83	0.40

Table 2 Trophic State of Main Urban Lakes in China (Unit: mg/L)

Lake Name	T-P	D-P	DO	Chl-a	SD*	T-N
Dongshan L.	0.420	0.051	6.93	132.03	0.29	6.10
Cihu L.	0.090	0.015	7.33	12.21	0.67	2.20
The West L.	0.170	0.070	8.28	56.58	0.55	3.10
Lihu L.	0.220	0.024	9.66	86.41	0.37	3.00
Gantang L.	0.240	0.130	8.03	43.23	0.55	1.70
Nanhu L.	0.310	0.049	8.85		0.36	4.80
Liuhua L.	0.530	0.037	1.14	239.53	0.19	6.40
Liwan L.	0.620	0.118	4.75	149.65	0.30	8.30
Mogu L.	0.600	0.036	7.40	30.21	0.64	2.40
Caohai of Dianchi L.	0.083	0.270	4.93	138.64	0.36	8.60
Mushui L.	0.740	0.1222	4.52	153.59	0.24	20.80
Xuanwu L.	0.970	0.180	8.31	99.28	0.27	3.90

Table 3 Trophic State of the Biggest Freshwater Lakes in China (Unit: mg/L)

Lake Name	T-P	D-P	DO	Chl-a	SD*	T-N
Taihu L.	0.052		9.00	5.35	0.50	2.14
Hongze L.	0.180	0.05	7.06		0.80	1.39
Boyang L.	0.148		7.87	1.05	0.55	2.38
Dongting L.	0.190		9.71	1.38	0.35	1.11
Caohu L.	0.204	0.046	7.95	14.98	0.25	2.30

Note L.: natural lake R.: artificial reservoir *: Unit of SD is m

2 Main Symptoms of Lake Eutrophication

2.1 Deterioration Of Water Quality

Excessive discharge of pollutants into lake is one of the important causes of eutrophication of lakes in China. Table 4 shows that now the ratio between present pollutant discharge and the maximal allowable load of the lake are of 3 to 10 in many lakes, and the value is even higher in urban lakes, which lead to deterioration of water quality and eutropohication of lake waters gradually.

2.2 Seriously Destruction Of Vegetation

Now aquatic vegetation in many lakes is commonly damaged due to deterioration of water quality, lowering of SD, and destruction of lakeshore and wetland. We illustrate in the following taking Lake Dianchi and Lake Erhai as two examples.

(1) Succession of Aquatic Plant Community of Lake Dianchi

Lake Dianchi is a typical case of rapid water pollution in China. It gradually evolved from a good water quality lake to a hypertrophic lake in the short term of recent three decades, as a result of which aquatic plant in the lake has been seriously damaged.

Table 4 Pollutant Load of Some Lakes in China

Lake	Present Pollutant Discharge(t/a)			Maximal allowable Load (t/a)		
	TP	TN	COD_{Cr}	TP	TN	COD_{Cr}
Dianchi L.	1021	8981	41672	356	5012	5754
Taihu L.	5168	72017	224032	587	2167	59532
Caohu L.	2677	26802	66773	225	5400	36036
Erhai L.	122	1154				
Yuqiao L.	228	4458		28	888	

Table 5 Change of Dominant Aquatic Plant Species in Lake Dianchi

Time	Species and families	Dominant species
50's	44 species of 28 families	*Ottelia acuminata* , *Ceratophyllum demersum*, and *Potamogeton*
70's	30 species of 22families	
80's	20 species of 12 families	*Myriophyllum spicatum* , *Eichhornia crassipes*

①Species

There were 4 species of 28 families of aquatic vascular bundle plants in Lake Dianchi in the 1950's, 30 species of 22 families in the 1970's but only 20 species of 12 families were founded by the end of 1980's(1988—1989), of which 12 species were submerged plants, 3 fluitantes and 5 emergent plants. Dominant species of the whole lake was Myriophyllum spicatum.

②Distribution and Biomass

The inner lake was over 2m deep in the 1950's, where the water was clean and there was rich water grass on the bottom of the lake and vegetation of the outer lake had a high coverage and with many types of communities.

By the end of 1980's, the area of aquatic vascular bundle plants in the outer lake was 366hm^2, with a biomass of 15,368.5 t (fresh weight, or 941 t of dry weight); that of the inner lake was 250hm^2, with a biomass of 1,250 t (fresh weight, or 656.25 t of dry weight). The total area of high aquatic plants in Lake Dianchi was 616hm^2, amounting to 20.5% of the total area of the lake, See Figure 2 for the change of aquatic plant distribution from the 1950's to the end of the 1980's.

③Aquatic Plant Community Structure and Succession

According to relevant data, aquatic vascular bundle plants in Lake Dianchi in the 1950's could be divided into 14 communities, including the unique community and some associated communities on the verge of extinction. Now there are 11 aquatic vascular bundle plants communities of different size in Lake Dianchi. The species of the communities have undergone remarkable changes as compared with those in the 1960's and the 1970's. It was reported that the communities of *Ceratophyllum demersum* and *Potamogeton pectinatus* had disappeard in the 1970's, but a few scattered communities have been founded again now.

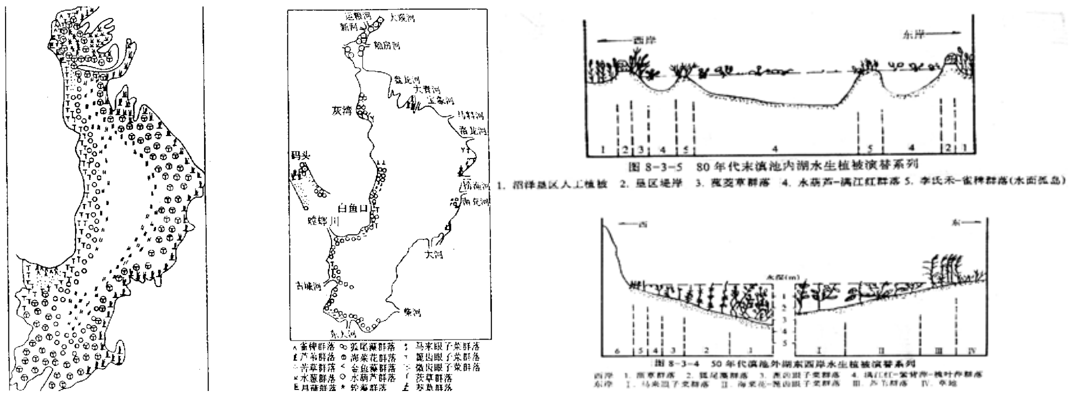

Fig. 2 Change Of Populations And Distribution Of Aquatic Plants Of Lake Dianchi(1950's–1980's)

The change of the aquatic plant communities suggest that some sensitive plant communities have disappeared or are facing extinction as eutrophication of the water body intensifies. The area of aquatic plants has declined and moved towards shallow parts of the lake and the ranges of plant communities is also getting smaller (except that of *Myriophyllum spicatum* community in Lake Dianchi).

The change in the ecoenvironment of the lake destroyed much of fish spawning ground in Lake Dianchi, over catching and interactions between different species of fish also caused much change in its species composition. For example, there were 15 original species of fish in the lake in the 1950's, accounting for 65.2% of the total amount of species of fish. There were only 4 species of original fish left in the 1980's, accounting for only 17.4%. The generally trend is original species are facing extinction and species introduced in are developing into dominant ones and the structure of fish communities is getting smaller.

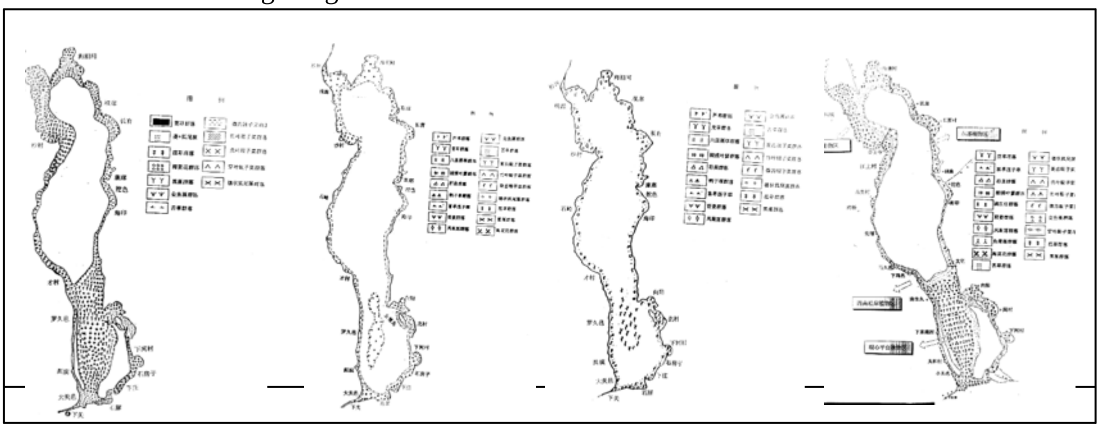

Fig. 3 Succession of Aquatic Plant Communities Of Lake Erhai (1977, 1985, 1994, 1998)

(2) Aquatic Plant Community Succession in Lake Erhai

Lake Erhai is the other type of case of water pollution in China. It has relatively good water quality and its pollution sources are mainly of non-point source together with higher in-lake pollution load due to in-lake activities. Vegetation of Lake Erhai has been destroyed since 1990's, the result of which is the break out of the whole lake “water blooms” in the autumn of 1996. Now “water blooms” has been controlled after taking some effective measures. In the following change of aquatic vascular bundle plant communities will be analysed reflecting progression of eutrophication of Lake Erhai.

Succession of aquatic vegetation in Lake Erhai can be divided into 4 stages:

①*Potamogeton pectinatus* + *Najas marina* stage

In the period of 1950–1960’s, Lake Erhai was in the state of oligotrophication with clean water, sparsely-distribution aquatic plants in deeper waters and relatively rich water grass in the littoral zone. Clean-water-loved species such as *Potamogeton pectinatus* and *Najas marina* were two dominant species in the lake. *Ottelia acuminata* can be seen in many lake bays and was also a dominant species.

②*Hydrilla verticillta* + *Potamogeton maackianns* + *Ceratophyllum demersum* + *Vallisneria spiralis* stage

After 1970’s, Lake Erhai transited from oligotrophic state to oligo-mesotropohic state, which lead to extension of aquatic plants continuously. Dominant species changed correspondingly and *Hydrilla verticillta* occupied the first dominant position, then is *Potamogeton maackianns*, *Ceratophyllum demersum*, and *Vallisneria spiralis*. While pollution-sensitive species such as *Ottelia acuminata* declined quickly.

③*Potamogeton maackianns* + *Vallisneria spiralis* + *Ceratophyllum demersum* + *Hydrilla verticillta* stage

In the later of 1980’s, Lake Erhai transited to mestrophication state with part of waters in eutrophic level. Correspondingly, pollution-resisting species *Potamogeton maackianns* took the place of *Hydrilla verticillta* and became the first dominant species of the lake, *Vallisneria spiralis* became the second dominant species, and *Hydrilla verticillta* and *Ceratophyllum demersum* especially *Hydrilla verticillta* declined quickly and became the third and fourth dominant species separately. While clean-water-loved species such as *Ottelia acuminata* 、*Potamogeton lucens* and *Potamogeton pectinatus* declined gradually.

④*Potamogeton maackianns* + *Vallisneria spiralis* + *Zannichellia palustris* + *Hydrilla verticillta* +*Ceratophyllum demersum* stage

In the end of 1990’s, some effective countermeasures were taken to treat pollution of lake Erhai. As a result, water quality has been improved greatly and submerged plants such as *Hydrilla verticillta*，*Potamogeton pectinatus*，*Potamogeton pectinatus*，and *Potamogeton lucens* began to restore, with rapid increase of area and biomass in the lake. But *Potamogeton maackianns* remains as the first dominant species as the lake is still in the high trophic level.

Table 6 Change of dominant species of Lake Erhai

Year	Species Number	Dominant Species
1957	—	Potamogeton pectinatus, Najas marina, Ottelia acuminata
1977	18	Hydrilla verticillt, Ceratophyllum demersum, Potamogeton maackianns, Potamogeton lucens
1985	15	Hydrilla verticillt (74.5%), Vallisneria spiralis(20.9%), Potamogeton maackianns (3.3%), Ceratophyllum demersum (0.47%)
1994	13	Potamogeton maackianns (57.5%), Vallisneria spiralis (24.7%), Ceratophyllum demersum (10.6%), Hydrilla verticillt (3.3%)
1998	13	Potamogeton maackianns (53.07%), Vallisneria spiralis (24.48%), Zannichellia palustris (6.67%), Hydrilla verticillt (6.53%), Ceratophyllum demersum (4.06%)

2.3 Frequent Break Out Of “Water Blooms”

In the recent years, mass algae growth occurred in Lake Dianchi, where concentration of Chla exceeding the standard by several hundreds’ times, and even several thousands’ times in the algae accumulated waters. And some waters of lake Caohu and Lake Taihu are always in the state of “water blooms”, too. Large areas of “water blooms” emerged in Lake Erahi in 1996.

Frequent emergency of “water blooms” in many urban lakes of China may do serious harm to the lake. First it may produce obstacle to water function of lakes, then it will have impacts on aquaculture and scenic tourism, and algae toxin will also endanger the health of people in the lake basin.

3 Theory and Countermeasure for Lake Eutrophication Control

3.1 Theory for Lake Eutrophication And Pollution Control

All kinds of irrational activities and excessive nutrient load into the lake are main causes of lake eutrophication and ecological disorder. Therefore, it requires to stop all kinds of artificial activities first and then take effective measures to restore lake ecosystem gradually to treat a lake basically.

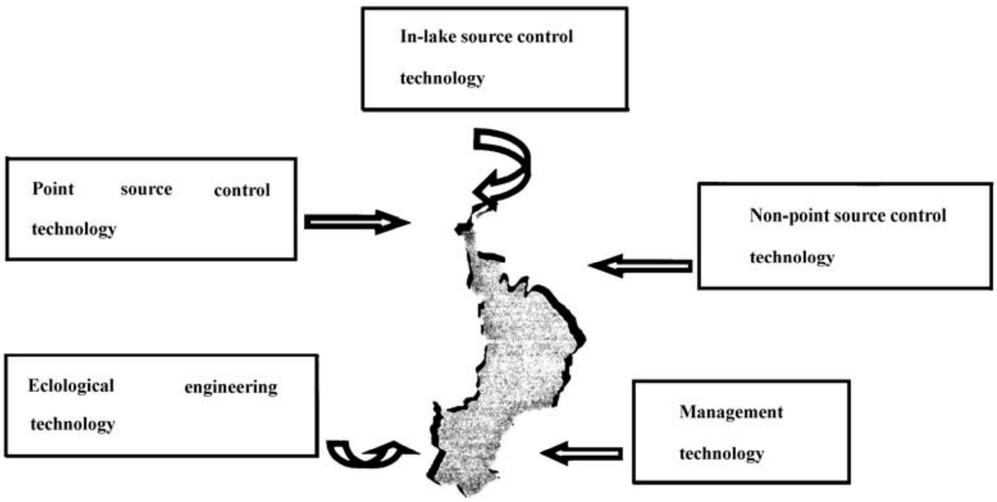

Fig. 4　Digram for Eutrophication Control of Lakes in China

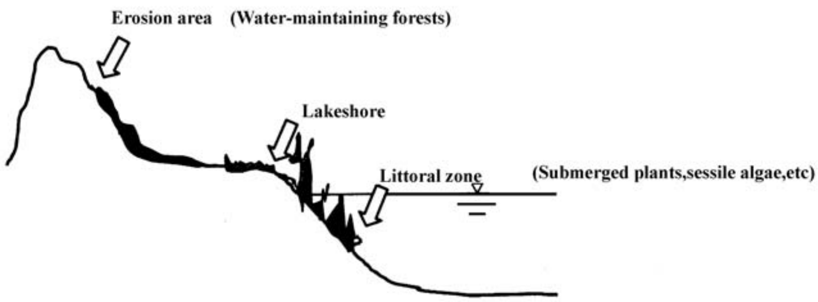

Fig. 5　Three regions for ecological restoration

Taking consideration on domestic and abroad experience and success demonstration, it puts forward theory for lake eutrophication control as follows:

(1)To combine source control with ecological restoration

Pollution sources are obviously the most direct causes of lake eutrophication, so control of pollution sources is regarded as the preliminarily step for eutrophication control. But lake is an alive waterbody and we cannot control eutrophication effectively with the single measure of source control. Lake eutrophication treatment requires to take not only source control measures but also ecological restoration measures which mainly pay attention to rehabilitation of aquatic plant in the shallow waters, restoration of lakeshore in the water-land crisscross area, and replantation of terrestrial ecological zone in erosion area.. Only through ecological restoration measures will lake ecosystem be restored to normal cycle and eutrophication be controlled basically.

(2)To protect lake from the point of view of the whole drainage

Lake is only part of a big ecosystem-the whole lake drainage. Therefore to maintain normal ecosystem requires to treat and protect lake from the point of view of the whole drainage area.

(3)The Synthetical Treatment and Management

It is proved to be more rapid profit's effect measure to synthetical treatment and management in prevention and treatment of lakes.

3.2 Countermeasures For Eutrophication

Countermeasures for eutrophication mainly include source control countermeasure, lake ecological restoration countermeasure, and management countermeasure.

(1)Source control countermeasure

Excessive load and accumulation of nutrients in lake are the principal causes of lake eutrophication. Therefore cut-down of loads of nutrients(internal and external) is the basic measure for source control.

①To decrease discharge of N and P into the lake

To calculate environmental capacity of N and P first, and then cut down load of point source and non-point source according to total amount control principle.

②To control in-lake pollution source

In-lake pollution source is also one of important sources of lakes, which mainly composed of polluted sediment, tourism pollution, aquaculture pollution, and boats and ships pollution, etc.

(2)Lake Ecological Restoration Countermeasure

Lake ecological restoration countermeasure is necessary measure for reestablishment of normal cycle of lake ecosystem, which is considered as the ultimate target of eutrophication treatment. Lake ecological restoration countermeasure generally has two components: lake water restoration and drainage terrestrial restoration.

(3)Lake Management Countermeasure

Management countermeasure is also very important in lake pollution treatment. It is regarded as a key task to rule out feasible and effectively management countermeasure.

It should be specially pointed out that synthetical treatment and management is the most effective measure for treatment of lakes already in the eutrophic state.

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Development of Advanced Water Renovation Systems Using Bio/ecoengineering for Establishing Sound Water Environment

Yuhei INAMORI [1], Kaiqin XU [1] , and Naohiro NODA [2]

1) National Institute for Environmental Studies, Tsukuba 305-0032, Japan

2) Department of Chemical Engineering, Waseda University, Tokyo 169-8555, Japan

Abstract Although water pollution in Japan passed through one-time critical situation, water environment has not been improved as expected. The compliance ratios of environmental quality standard indexes such as BOD and COD measures in rivers, lakes and sea areas, were 81.0%, 40.9% and 73.6% in 1999, respectively, which still remains in low levels. The water bodies are extremely eutrophic because of the direct discharging of gray water, which represents a substantial portion of the total household effluents, and the wastewater from the small scale factories. They are almost 70 % of the total pollutants in public water areas. On the other hand, as for the environmental quality standards relating to nitrogen and phosphorus in 60 determined lakes and 112 sea areas were 38.3% and 70.5%. The removal of nitrogen and phosphorus in effluent from domestic and industrial wastewater treatment facilities is most important to control the eutrophication. In this paper, new environmental problems caused by blue-green algae, necessity and improvement of nitrogen and phosphorus removal technology using bio-ecoengineering, and some advanced national projects conducted in National Institute for Environmental Studies were presented.

Key-words Eutrophication Blue-green algae Bio-ecoengineering, nitrogen Phosphorus Johkaso Lake

1 Introduction

The environmental quality standards relating to the protection of human health in Japan were amended from nine items into twenty three items in March 1993, and the compliance ratios were more than 99.5% in 1999. However, the compliance ratios of BOD/COD for rivers, lakes and coastal waters were 81.0%, 40.9% and 73.6%, respectively, which still remains in low levels (Environment Agency, 1999). Especially in urban rivers, lakes, inland sea and bays, the water bodies are extremely eutrophic because of the direct discharging of gray water, which represents a substantial portion of the total household effluents, and the wastewater from the small scale factories. They are almost 70 % of the total pollutants in public water areas. On the other hand, as for the environmental quality standards relating to nitrogen and phosphorus in 60 determined lakes and 112 sea aeras were 38.3% and 70.5%. The removal of nitrogen and phosphorus in effluent from domestic and industrial wastewater treatment facilities is most important to control the eutrophication.

Table 1. Poisonous freshwater blue-green algae and its toxic substances

Anabaena flos-aquae	Anatoxin Microcystin
Aphanizomenon flos-aquae	Aphantoxin Cyanoxinocyn
Microcystis aeruginosa	Microcystin
Microcystis viridis	Microcystin
Nodularia spumigena	Nodularin
Oscillatoria agardhii	Microcystin

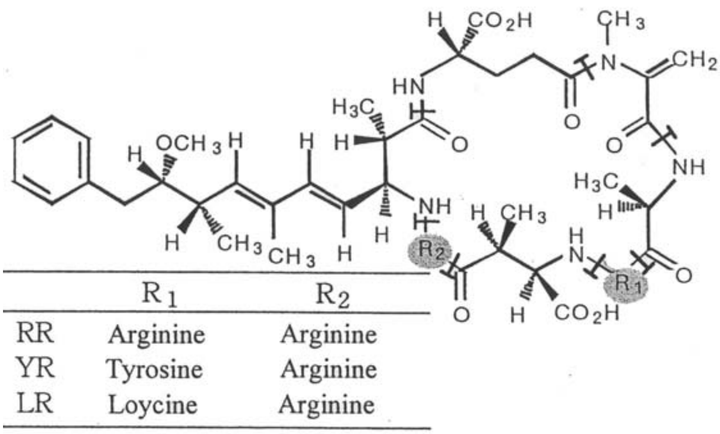
*Anatoxin and aflatoxin are neuroactive poison and all others are liverish poison.
Toxic substances are contained or not contained for different roots.

The extreme growth of poisonous picoplankton and the occurrence of water bloom even caused the crisis of water supply systems. The control of micro pollutants such as organochloride and agricultural pesticides is also an urgent problem. Some successful results have been reached through the cooperative studies of government, companies and research institutes. Some of the acquired new technologies have been applied to the practical use. At the meantime these technologies are adopted as advanced treatment methods and begun to spread to whole country. Among them the application of the ecotechnology and biotechnology is one of the important tasks for the treatment of wastewater and the conservation of water environment.

The purpose of this study is to introduce the new environmental problems caused by blue-green algae, necessity and improvement of nitrogen and phosphorus removal technology using bio-ecoengineering, and some advanced national projects conducted in NIES. The application of ecotechnology and biotechnology to the restoration of water environment field in Japan were also discussed (Inamori et al, 1993, 1995, 1996, 1998).

2 New Environmental Problems Caused by Blue-green Algae Around the World

The growth of toxic blue tide and toxic picoplankton caused by blue-green algae has already been observed in a number of bodies of water, and gotten more ugly. Regarding the problems posed by these toxic algae, at an international conference held in Denmark in August 1995, it was pointed out that there is a great potential for toxic substances to cause an international water supply source crisis (Table 1) (Saito, 1994), prompting a study of the positioning of guidelines with the World Health Organization (WHO), then in December 1998, 1 mg/L was set as the Microcystin density. In Japan, high concentrations of Microcystin (Fig. 1) have been detected in Kasumigaura, Inba Marsh, and other areas where blue tide is concentrated (Fig. 2), so urgent measures must be taken to guarantee that their water is safe to use. These toxic algae etc. are extremely prone to propagate abnormally when the N/P ratio is particularly high, raising fears that they might cause serious public problems. This danger has appeared in Brazil where 47 dialysis patients died from drinking water containing Microcystin caused by toxic blue tide in April 1996. At Kasumigaura, the N/P



	R1	R2
RR	Arginine	Arginine
YR	Tyrosine	Arginine
LR	Loycine	Arginine

Fig. 1 Structure of microcystiin that produces poisoncus water bloom which is stronger than pottasium cyanide

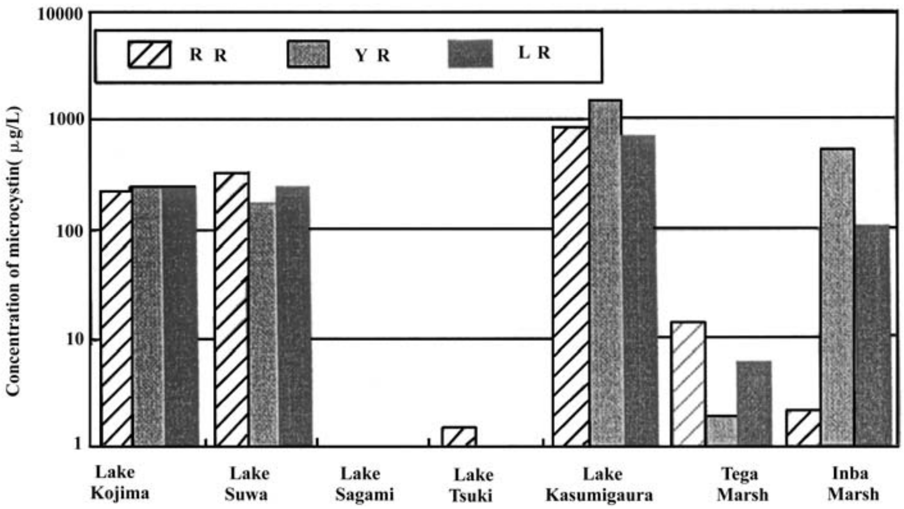


Fig. 2 Microcystin concentration in water surfaces covered by water bloom

ratio that was 12 in 1980 had risen to 21.4 by 1988, and although it has declined recently, the N/P ratio of incoming river water remains remarkably high(Sugiura, 1994). As a result of a rising N/P ratio in the hydrosphere and other changes in the water environment, in the summer, filamentous blue-green algae such as Phormidium or Oscillatoria become dominant in place of the dominant type Microcystis and continue to occur throughout the year so that even in the winter, COD tends to rise creating critical conditions. Because Oscillatoria is so cold-resistant that it can survive underneath ice, during the winter, it lowers its transparency, increasing the annual average COD level, with the result that the water quality in Kasumigaura has declined in recent years. And in the Pocomoke River that flows into Chesapeake Bay in Maryland in the U.S., the effluence of poultry farm wastewater has hastened eutrophication, resulting in the extensive propagation of the aggressive Protozoa fuiesuteria picicida and the resulting death of hundreds of thousands of fish. It is absolutely essential to develop and introduce measures to reduce nitrogen, phosphorus, and the N/P ratio because such an increase in the N/P ratio and other changes in the environments of closed bodies of water cause changes in the microorganism community structure of the ecosystem that consists of Protozoa, algae, and bacteria, inviting increasingly severe environmental pollution.

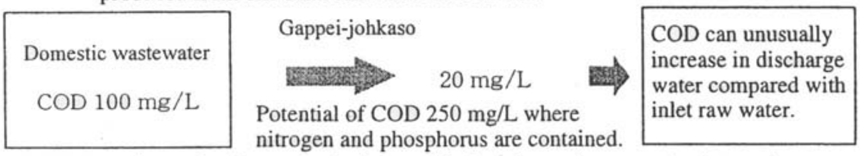
3 Necessity for Nitrogen and Phosphorus Removal Technology to Create Sound Water Environments

In lakes, marshes, inner harbors, inland seas, and other closed bodies of water and in small and medium size rivers flowing through cities, pollution is gradually accelerating, and it is recognized that the percentage of sources of the total pollution load that is accounted for by industrial wastewater is falling steadily and the load imposed by domestic waste water is increasing. This change has taken place because the strengthening of regulations governing industrial wastewater under the Water Pollution Control Law has shifted most of the pollution load to domestic wastewater that has not been covered by the regulations. This means that measures to deal with domestic wastewater that accounts for 70% of the incoming pollution load sources are essential if the environments of closed bodies of water are to be preserved. Because the existence of night soil treatment johkaso that discharge domestic miscellaneous wastewater and domestic wastewater treatment johkaso that do not remove nitrogen and phosphorus pose a serious problem, the implementation of measures to eliminate them is an extremely important public issue. In addition to introducing measures to deal with nitrogen and phosphorus from untreated domestic wastewater and miscellaneous domestic wastewater, it is also absolutely essential to improve present facilities that process night soil and sewage treatment plants by providing them with the capacity to remove nitrogen and phosphorus and to take emergency steps to provide radical measures focused on nitrogen and phosphorus that are substances causing eutrophication. In brief, it is absolutely essential to implement nitrogen and phosphorus reduction measures because even if it is possible to reduce the quantity of incoming organic substances through measures to fight pollution load sources, if nitrogen and phosphorus continue to flow in, algae propagates in closed bodies of water and this internal production of algae results in an increase in the concentration of organic substances in the hydrosphere. For example, in the case of treated water T-N 30 mg/L and T-P 3 mg/L discharged from a domestic wastewater treatment facility with treatment capacity of BOD 20 mg/L, the algae growth potential (AGP) is 500 mg per 1 L of treated water as shown in Table 2, and if this is converted to CODMn, it is approximately 250 mg (blue-green algae mass 1 mg ≒ 0.48 mgCOD). As long as nitrogen and phosphorus are not removed in this way, even if the COD100 mg/L in domestic wastewater is reduced to 10 mg/L, in a closed body of water, the water will be discharged retaining the capacity to increase the COD to a level of 250 mg/L, so needless to say it is essential to improve the system's capacity to remove nitrogen and phosphorus.

Table 2 Typical AGP in final effluent discharged from combined aeration-type Johkaso

Provided *Cyanobacteria* \ Facilities	AGP (mg/L) A	B	C	D	Average
Selenastrum capricornutum	430	520	590	580	530
Chlorella sp.	290	370	440	370	368
Chattonella sp.	450	430	430	390	425

If AGP measured is 500 mg/L or less, CODMn of 250 mg is produced from one final effluent from Johkaso.



AGP Test : An evaluation method of potential algae increasing capacity that evaluates specimen water for capacity of increasing algae in public water areas through testing with flasks filled with treated wastewater to inoculate the specimen water with algae and to measure the increased number of algae at maximum after cultivation of 10 days under direct lighting.

4 Administrative Trends in Nitrogen and Phosphorus Removal for Sound Water Environment

The principal sources of nitrogen and phosphorus pollution loads are assumed to be point source pollution loads such as domestic wastewater and hog farms plus non-point source pollution loads that include farms, roads etc., and in addition to progress in the provision of sewage treatment systems to deal with nitrogen and phosphorus in domestic wastewater, community plants, farm village wastewater treatment facilities, domestic wastewater treatment johkaso, and various kinds of domestic wastewater treatment facilities are being constructed according to circumstances in each region.

The Environmental Agency designates domestic wastewater measure priority regions, prepares and implements domestic wastewater measure promotion projects, provides assistance with the provision of water purification facilities, and carries out public educational campaigns to increase awareness of domestic wastewater measures. In 1997, it designated a total of 7 prefectures, 11 regions, and 25 municipalities so that by the end of March 1998, had designated a total of 40 prefectures, 178 regions, and 432 municipalities as domestic wastewater measure priority regions. In 1991 in domestic wastewater measure priority regions, the Environmental Agency began to assist with the provision of facilities to purify water in waters with particularly high levels of pollution by domestic wastewater by carrying out 1) domestic wastewater polluted waterway purification facility construction projects and 2) simple domestic wastewater pollution improvement facility construction projects. It also began a public relations campaign by holding water environment forums, issuing public bulletins, and distributing pamphlets in order to increase people’s consciousness of water quality conservation and to help popularize the implementation of pollution source control measures inside private homes.

Table 3. Treatment method and performance for domestic wastewater treatment facilities (Gappei-Johkaso) as generally evaluated already with respect to the removal of nitrogen.

No.	Treatment method	Effluent quality (mg/L)	Representative features	Typical operating conditions
1	Flow rate cotrol type anaerobic-aerobic circulation filter bed process	BOD : 15 T-N : 15 SS : 20	High performance removal of BOD, nitrogen and SS, by circulation from aerobic condition to anaerobic condition, and by inflow peak cut by fixing the water-level fluctuation of all tanks and the amount of effluent.	BOD volumetric load in the contact aeration tank : 0.3 kg/m3/day, T-N volumetric load : 0.075 kg/m3/day, Circulation ratio : 2-3, Inflow rate peak cut by the water-level fluctuation of all tanks.
2	Flow rate cotrol type anaerobic filter bed/biological filtration circulation process	BOD : 10 T-N : 20	High performance removal of BOD, and nitrogen by circulation from aerobic condition to anaerobic condition, and by flow rate control to feed a given amount of water to the aerobic biological treatment tank, and by the combined use of biological filtration.	BOD volumetric load in the biological filtration tank : 0.857 kg/m3/day, T-N volumetric load : 0.21 4 kg/m3/day, Carrier filling factor : 90%, Filling carrier : made of polyethilene, Circulation ratio : 3.
3	Flow rate cotrol type anaerobic filter bed/ biofilm filtration circulation process	BOD : 10 T-N : 10 SS : 10	High performance removal of BOD, nitrogen and SS, by circulation from aerobic condition to anaerobic condition, and by flow rate control to feed a given amount of water to the aerobic biological treatment tank, and by the combined use of biofilm filtration.	BOD volumetric load in the biofilm filtration tank : 1 kg/m3/day, T-N volumetric load : 0.25 kg/m3/day, Carrier filling factor : 70%, Filling carrier : made of porous ceramic, Circulation ratio : 4.
4	Flow rate cotrol type anaerobic filter bed/ contact aeration circulation process	BOD : 10 T-N : 15	High performance removal of BOD, nitrogen and SS, by circulation all out aeration from aerobic condition to anaerobic condition, and by inflow peak cut by fixing the water-level fluctuation of all tanks and the amount of effluent.	BOD volumetric load in the contact aeration tank : 0.2 kg/m3/day, T-N volumetric load : 0.052 kg/m3/day, Circulation ratio : 4, Inflow rate peak cut by the water-level fluctuation of all tanks.
5	Flow rate cotrol type anaerobic filter bed/biological filtration circulation process	BOD : 10 T-N : 15	High performance removal of BOD, and nitrogen by circulation from aerobic condition to anaerobic condition, and by flow rate control to feed a given amount of water to the aerobic biological treatment tank, and by the combined use of biological filtration.	BOD volumetric load in the biofilm filtration tank : 0.6 kg/m3/day, T-N volumetric load : 0.15 kg/m3/day, Carrier filling factor : 65%, Filling carrier : made of foamed ppolystyrene, Circulation ratio : 2-5.
6	Flow rate cotrol type anaerobic filter bed/ periodic backwash contact aeration circulation process	BOD : 10 T-N : 15	High performance removal of BOD and nitrogen, by circulation all out aeration from aerobic condition (periodic backwash) to anaerobic condition, and by flow rate control to feed a given amount of water to aerobic biological treatment tank.	BOD volumetric load in the contact aeration tank : 0.2 kg/m3/day, T-N volumetric load : 0.05 kg/m3/day, Circulation ratio : 3.
7	Flow rate cotrol process combined with anaerobic filter bed, carriier floating aeration, and high-speed solid-liquid separation process	BOD : 10 T-N : 10 SS : 10	High performance removal of BOD, nitrogen and SS, by circulation from aerobic condition to anaerobic condition, by flow rate control to feed a given amount of water to the aerobic biological treatment tank, and by combined use of fluidized aeration with small cylindrical carriers and high-speed solid liquid separation with such carriers.	BOD volumetric load in the carrier floating aeration tank : 0.4 kg/m3/day, T-N volumetric load : 0.1 kg/m3/day, Filling carrier : polyethilene, Circulation ratio : 2.
8	Flow rate cotrol type agitaion filter bed/biofilm filtration circulation process	BOD : 10 T-N : 10	High performance removal of BOD, and nitrogen by circulation from aerobic condition to anaerobic condition, and by inflow peak cut by fixing the water-level fluctuation of all tanks and the amount of effluent, and further by biofilm filtration.	BOD filter material volumetric load in the biofilm filtration tank : 0.96 kg/m3/day, T-N filter material volumetric load : 0.24 kg/m3/day, Carrier filling factor : 63%, Filling carrier : porus ceramic, Circulation ratio : 4.
9	Anaerobic filter bed/contact aeration circulation process	BOD : 15 T-N : 20	High performance removal of BOD, and nitrogen by batch treatment by transffering wastewater in batch from the aeration filter bed tank to the biological treatment tank (contact aeration tank), and by anaerobic-aerobic inttermittent aeration (timer) in the contact aeration tank.	BOD volumetric load in the contact aeration tank : 0.174kg/m3/day, T-N volumetric load : 0.043 kg/m3/day, Contact material filling factor : 55%, Constant treatment by batch type operation.

(Continued)

No.	Treatment method	Effluent quality (mg/L)	Representative features	Typical operating conditions
10	Flow rate cotrol type anaerobic filter bed/ contact aeration circulation process	BOD : 10 T-N : 15	High performance removal of BOD and nitrogen, by circulation all out aeration from aerobic condition (periodic backwash) to anaerobic condition, and by flow rate control to feed a given amount of water to aerobic biological treatment tank.	BOD volumetric load in the contact aeration tank : 0.2 kg/m3/day, T-N volumetric load : 0.05 kg/m3/day, Circulation ratio : 4.
11	Flow rate cotrol type anaerobic filter bed/ contact aeration circulation process	BOD : 10 T-N : 15	High performance removal of BOD and nitrogen, by circulation all out aeration from aerobic condition (periodic backwash) to anaerobic condition, and by flow rate control to feed a given amount of water to aerobic biological treatment tank.	BOD volumetric load in the contact aeration tank : 0.22 kg/m3/day, T-N volumetric load : 0.055 kg/m3/day, Circulation ratio : 3-5.
12	Flow rate cotrol type denitrification biofilm/biological filtration circulation process	BOD : 10 T-N : 15	High performance removal of BOD, and nitrogen by circulation from aerobic condition to anaerobic condition, and by flow rate control to feed a given amount of water from the aerobic solid matter removal tank to the anaerobic denitrification biofilm tank, and further by the combined use of biofilm filtration.	BOD volumetric load in the biofilm filtration tank : 0.6 kg/m3/day, T-N volumetric load : 0.15 kg/m3/day, Carrier filling factor : 60%, Filling carrier : porus carrier of polypropilene , Circulation ratio : 3.

The Ministry of Construction has set target sewerage treatment system penetration rates about 70% for 2000 and about 90% for the early Twenty-first Century and enacts and implements Seven Year Sewage Treatment System Construction Plans. In 1997, which was the second year of the Eighth Seven Year Sewage Treatment System Construction Plan (total cost: 23.73 trillion yen), it was constructing systems in medium and small municipalities where the penetration was delayed, starting new projects in municipalities where no sewage treatment systems had been provided, was working to improve the quality of existing sewage treatment systems in large cities by aggressively introducing advanced treatment systems to preserve water quality, and was encouraging multi-purpose use of sewage treatment resources such as treated wastewater etc. And by reviewing and revising structural standards for domestic wastewater treatment tanks (johkaso), it was completing a set of structural specifications that would permit advanced removal of nitrogen and phosphorus. Among these, Notification No. 13 New Structural Standards that broke with the approaches in Notifications No.1 to No. 12 by introducing approval testing of technological levels, quality management, etc. in design and execution focussed on treatment performance during corroborative testing, now plays an important role in the encouragement of the practical application of various new technologies and the establishment of technologies that benefit the public (Table 3). Provisions in Notification No. 13 concerning domestic wastewater treatment tanks sharply reduced the corroborative test period so that it now takes about 6 months to obtain an evaluation instead of more than 1 year as in the past in order to encourage the more rapid introduction of new technologies throughout society. To perform these evaluations, the Household Night Soil Treatment Tank Performance Evaluation Committee (Chairman: Professor Sudo Ryuichi of Tohoku University) of the Building Center of Japan that is an external agency of the Ministry of Construction determines whether approval is to be given based on careful investigations. The stipulation of nitrogen and phosphorus standards in the performance standards in the Enforcement Order of the

Building Standard Law of Japan will be studied based on the concepts of new structural standards in Notification No. 13 that are considered standards for domestic wastewater treatments that will soon appear (Table 4).

At the same time as the Ministry of Health and Welfare is in charge of maintenance of domestic wastewater treatment facilities, it is taking steps to deal with domestic wastewater by conducting Domestic Wastewater Treatment Johkaso Installation Projects and the Designated Region Domestic Wastewater Treatment Project, and by installing community plants.

The Designated Region Domestic Wastewater Treatment Project established in 1994 has approved wide-area improvement projects with municipal governments in charge of installation (public management) in regions such as public water system supply regions and others where there is an urgent need to deal with domestic wastewater. Although along with the enactment of the Law Concerning the Promotion of the Implementation of Public Water System Supply Region Water Quality Preservation, this project is, aimed at wide-area provision in planning regions in accordance with the same law, beginning in 1995, it was expanded to include designated regions under the Lakes and Ponds Law and depopulated regions. The Ministry of Health and Welfare is dealing with waste material treatment facilities that include domestic wastewater treatment johkaso by positioning the encouragement of the provision of domestic wastewater treatment johkaso in the Seventh Five Year Plan (1991–1995) based on the Law on Emergency Measures for Waste Material Treatment Facility Improvement and enacting plans calling for all newly installed domestic wastewater treatment tanks to be domestic wastewater treatment johkaso under the Eighth Five Year Plan. These plans stipulate that by the end of 2000, it be possible to appropriately treat domestic wastewater produced by 14% of the population (8% at the end of 1995) in domestic wastewater treatment johkaso, with the five year project to cost a total of 554 billion yen and provide service to 6.94 million people. This is a project plan that is 2.08 times as expensive as that proposed by the seventh plan.

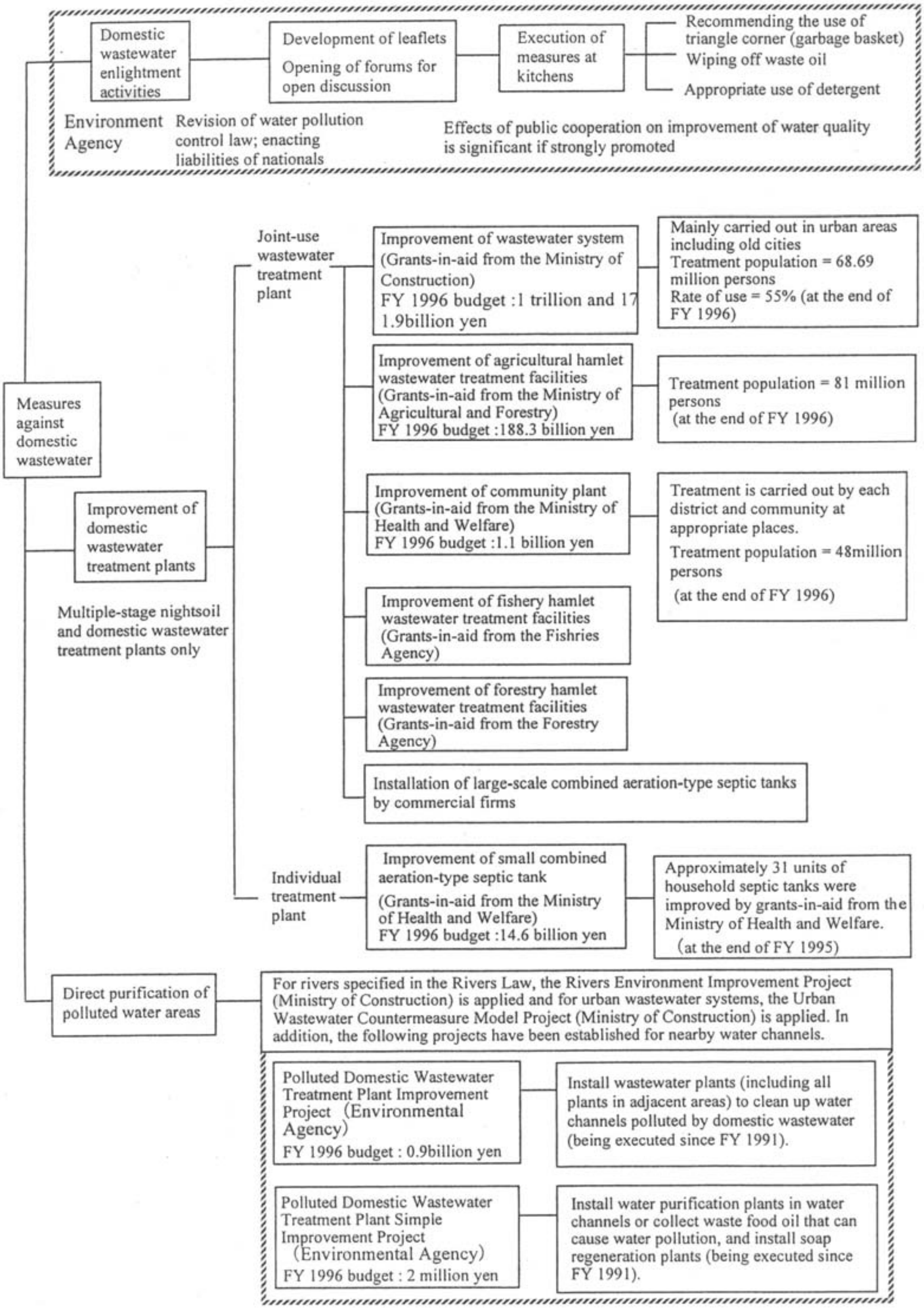
The Domestic Wastewater Treatment Johkaso Installation And Improvement Project, that provides subsidies to municipalities that support the installation of compact domestic wastewater treatment johkaso, was introduced and implemented in 1987. When a municipality subsidizes the difference between domestic wastewater treatment johkaso and night soil treatment johkaso, the National Government pays 1/3 of that amount. In the draft budget for 1999, the Ministry of Health and Welfare allocates a total of 16.07 billion yen that is 4.6% more than the previous year to domestic wastewater treatment johkaso in1991. In the regulatory area, higher standard amounts than the present National Treasury Subsidy Standard Amount will be newly established for nitrogen removal type advanced domestic wastewater treatment johkaso while the Ministry of Health and Welfare will adopt a policy of aggressively promoting measures to remove nitrogen and phosphorus in order to improve the quality of water in public bodies of water..

Table 4 Concept of performance criteria for Johkaso as measures against domestic wastewater

Areas where nightsoil treatment tanks are installed *	Number of persons per tank	Performance		
		Biological oxygen demand (BOD) for final effluent from nightsoil treatment tanks (mg/L)	Total nitrogen (T-N) for final effluent from nightsoil treatment tanks (mg/L)	Total phosphorus (T-P) for final effluent from nightsoil treatment tanks (mg/L)
(A)		10 or less	10 or less	10 or less
(B)	200 or less	20 or less	20 or less	—
	201 or more 500 or less	10 or less	15 or less	1 or less
	501 or more	10 or less	10 or less	1 or less
(C)	500 or less	20 or less	—	—
	501 or more	10 or less	15 or less	1 or less
(D)	50 or less	90 or less	—	—
	51 or more 500 or less	60 or less	—	—
	501 or more	30 or less	—	—
(E)	500 or less	90 or less	—	—
	501 or more 2,000 or less	60 or less	—	—
	2,001 or more	30 or less	—	—

*For (A) through (E), a regional designation is required based on the achievement rate of water quality standards including nitrogen and phosphorus, taking into account the characteristics of water source areas, eutrophic water areas, and inner bay areas of the designated 88 lakes.

The Ministry of Agriculture and Forestry has designated the preservation of the quality of water discharged from farms and the improvement of the living environment of farming communities as priority measures and is promoting the construction of agricultural hamlet wastewater treatment facilities. Agricultural hamlet wastewater projects include laying conduits and constructing polluted water treatment systems, sludge composting plants, and other systems needed to treat polluted water such as excreta and miscellaneous domestic wastewater from farming hamlets, and are carried out where the quantity to be processed is no greater than that produced by 1,000 people. In 1997 the cost of these projects leaped to 145.4 billion yen with the wastewater produced by about 888,000 people being processed at the end of 1996 and both the cost and population served are expected to continue to grow rapidly. The Fisheries Agency is providing fishing hamlet wastewater treatment facilities and the Forestry Agency is providing forestry hamlet wastewater treatment facilities. The recently undertaken effort to create systems suitable for farming regions by linking ecoengineering technology such as aquatic plant purification with farming and forestry hamlet wastewater treatment facilities is expected to make a big positive contribution.



Fgi. 3 Countrmeasure system agamst aomestic wastewater

Turning to the role of the Ministry of Home Affairs, although various ministries and agencies are conducting domestic wastewater treatment facility construction or improvement projects, the bodies actually in charge of these facilities are municipalities. This means that the Ministry of

Home Affairs is actively involved by, in addition to assisting concerned ministries, introducing financial measures such as regional tax grants and regional bonds(sewage treatment system construction bonds), etc. The self-support ratio for the installation of combined domestic wastewater treatment facilities during the current year is 10%, generally equal to that for public sewage systems, indicating that such policies are optimal and will effectively spread the use of advanced compound domestic wastewater treatment facilities.

Turning to regional self-governing bodies, in Shigamura, a town in Nagano Prefecture, a wide-area domestic wastewater treatment tank improvement project limited to advanced compact combined domestic wastewater treatment facilities that can remove nitrogen has been underway since 1993 in order to guarantee the quality of water for agricultural use and to assure sources of water for the public water supply system. This improvement project is being conducted based on a plan calling for the provision of advanced compact combined domestic wastewater treatment facilities to 1,400 households out of a total of 1,970 households with 6,500 members. The local government is exercising overall control of the entire improvement project that includes the selection of the advanced combined domestic wastewater treatment facilities, educating the residents about the introduction of advanced compact combined domestic wastewater treatment facilities, and installing, and maintaining the new treatment facilities. After each advanced compact combined domestic wastewater treatment facilities is installed, a maintenance ledger is prepared for the household where it is installed. These ledgers are not only used for maintenance and resolving system problems; provided for the scrutiny of the general public, they serve as a public information system that stimulates people’s interest in domestic wastewater facilities. A third sector organization is scheduled to eventually take over centralized maintenance of these facilities and to conduct studies that will include the transformation of the sludge they produce into fertilizer.

This improvement project in Shigamura has even attracted the attention of foreign countries as an ideal approach to the provision of domestic wastewater treatment facilities.

Policies related to domestic wastewater measures are being conducted by the Science and Technology Agency, the Environmental Agency, Ministry of Health and Welfare, Ministry of Construction, the Ministry of Agriculture and Forestry, and other concerned ministries and agencies and by regional public bodies as described above, but the essential goal of domestic wastewater measures is still the improvement of the water quality in public water bodies, and to achieve this goal, it is still necessary to put top priority on measures to eliminate nitrogen and phosphorus (Fig. 3).

5 National Projects Intended to Create Sound Water Environments Through the Introduction of Advanced Treatment Systems

In the face of urban and domestic pollution including water environment contamination, soaring volumes of waste material, a decline in nearby greenery, and the appearance of global scale environmental problems and in response to a growing public awareness of the necessity for a new framework for measures based on sustainable recycle systems, the Basic Environment Plan has been enacted based on the concept: "maintain the limited global environment that is the common foundation for the coexistence of mankind, receive and pass on the blessings of the environment, and at the same time, draw upon the wisdom of our ancestors to reassess modern civilization, and transform our modes of production and living into sustainable patterns. Among these basic policies, the long term goals are defined as "the realization of an economic and social system featuring cycles that place little load on the environment as its keynote" and creating zero-emission life styles, constructing industries, and creating industrial forms are measures indispensable for the realization of the ideals of the Environment Basic Law.

In these circumstances, "The research on the construction of resource cycle type eco-systems to contribute to the sustained use of the environment and resources" was initiated in 1995 as a new research theme of the Science and Technology Agency program, "Research to Meet Consumer’s Needs" by a group including the National Institute for Environmental Studies, the Building Research Institute, Tohoku University, Tsukuba University, and Association for Formal Household Sewage Treatment Tank, etc. Its principal goals are the resolution of various problems caused by waste material in the cities and elsewhere and the construction of resource cycle eco-systems to contribute to the sustainable use of resources with low load on the environment that will satisfy the needs of society in the Twenty-first Century. The results of this research are sure to be extensively applied to daily life and society by stimulating science and technology that emphasizes the perspective of ordinary people and by serving as foundation research that will stimulate regions where people lead their lives.

The project entered the second stage in 1998. As a measure to deal with existing household night soil treatment facilities, Association for Formal Household Sewage Treatment Tank intends to develop and popularize compact advanced combined domestic wastewater treatment facilities that are the same size as household night soil treatment facilities and are capable of treating night soil and miscellaneous domestic wastewater. "Research on performance corroboration and evaluation analysis of model regional installations of advanced simple compact prototype domestic wastewater treatment tanks" is being conducted as compact domestic wastewater treatment tank corroborative experiments based on the results of influent load 1X, 2X, and 3X load experiments using the flow equalization anaerobic filter bed/contact aeration process, flow equalization anaerobic filter bed/biological filter process, and flow equalization impurity removal tank/membrane separation process obtained during the first stage. And based on results obtained by the Advanced Household Sewage Treatment Tank Research Committee is using membrane separation technology of the Public Works Research Institute of the Ministry of Construction (Fig. 4) .

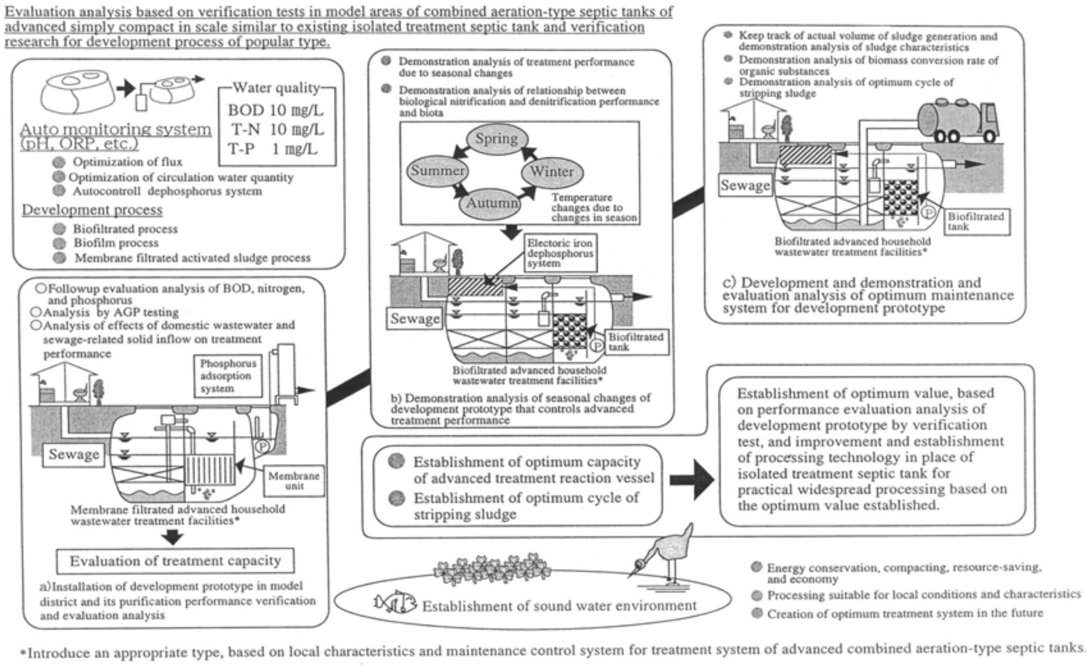


Fig. 4 Research on performance evaluation analysis of advanced simply compact prototype septic tank installed at model district

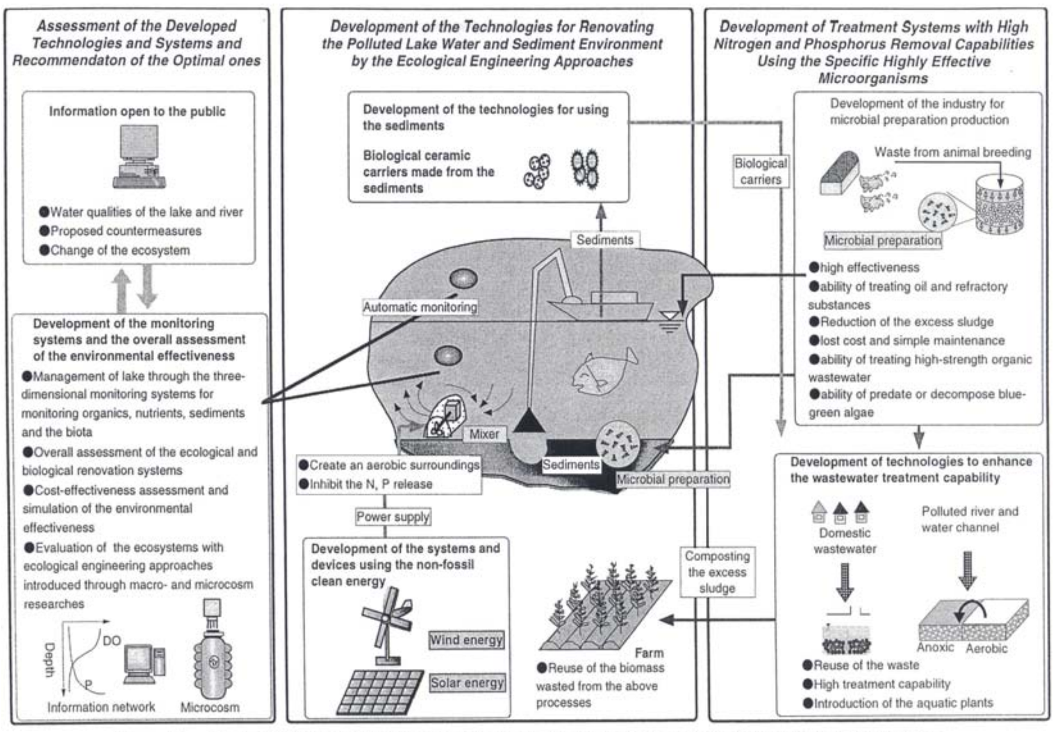
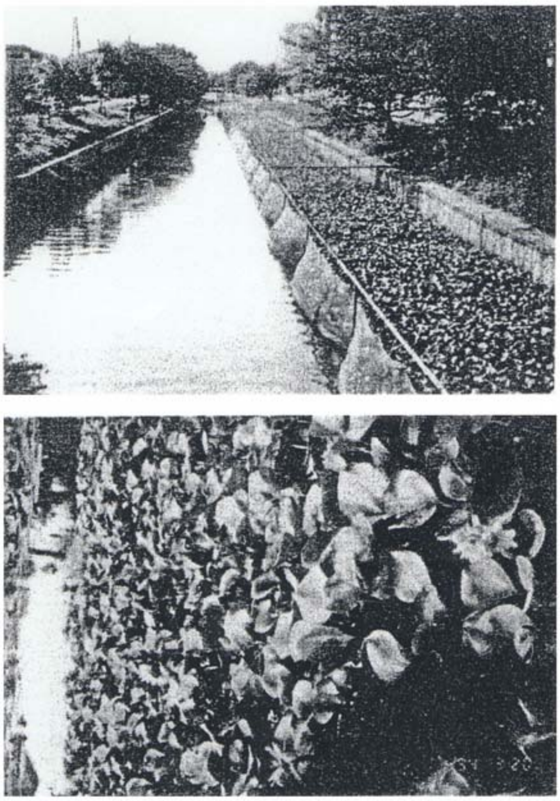
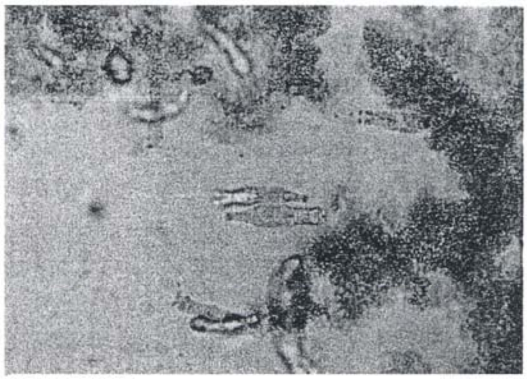


Fig. 5 Development of water environment restoration technology for polluted lake water areas with ecological engineering and flow of promoting research on comprehensive evaluation of improvement effects by system introduction

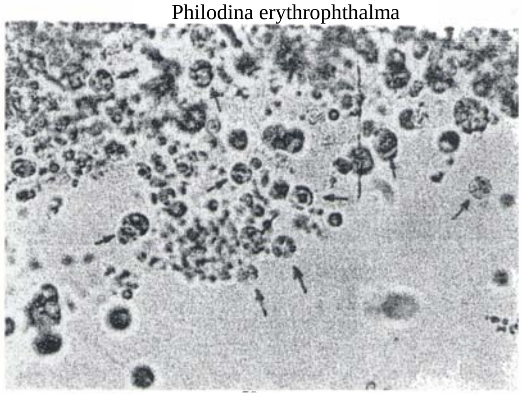
In Ibaraki Prefecture, a National Project organized as a joint industry, government, academia research project intended to establish environmental restoration technology including measures to decontaminate the waters of Kasumigaura was initiated as a five-year plan in 1997. This joint research project conducted under the leadership of the Regional Science and Technology Promotion Section of the Research Foundation Department of the Science and Technology Promotion Bureau of the Science and Technology Agency, is "research on overall evaluations of the improvement effects of the development and application of water environment restoration technology using eco-engineering for contaminated lake and marsh waters" intended to restore the soundness of contaminated lakes and marshes that is the most serious problem in Ibaraki Prefecture. An outline of the research is shown in Figure 5.

This joint research project involves technological development premised on ecosystem conservation related to the restoration of water environments through the application of eco-engineering and the achievement of environmental standards accompanied by the analysis and evaluation of effects and influence on ecosystems of measures to deal with production sources, the improvement of treatment technology used for direct decontamination, and the introduction of treatment systems (Photographs 1, 2).





200μm
Philodina erythrophthalma



50μm
Monas guttula

Photograph 1 Water purification system using aquatic plants

Photograph 2 Protozoa as predatory of blue green algae

Specifically, the goals of this project include the development of a high efficiency decontamination system using useful microorganisms that can achieve target values of BOD 10 mg/L or less, T-N 10 mg/L or less, and T-P 0.5 mg/L or less considering the rise in the phosphorus concentration that has been manifest in Kasumigaura along with an advanced expanded type combined new treatment process for use in a high function version of a type known in the past as an irregular combined domestic wastewater treatment tank; focusing on the development of a direct river decontamination process that cansatisfy target water quality values of BOD 5 mg/L or less, T-N removal rate of 70% or greater, and a T-P removal rate of 70% or greater, corroborative development research conducted by applying the technologies at the core of these processes to actual sites, the development of measurement and monitoring system technology to be used to analyze and evaluate the water quality improvement effects of actually introducing these processes, cost effects, and the establishment of technology needed for the most appropriate form of wide area provision of these processes; the establishment of high efficiency domestic wastewater treatment tank treatment technology based on high-functioning microorganisms that are obtained, technology to transform biomass sludge into resources, direct river decontamination technology utilizing unexploited regional resources, and new technologies such as electric power supply technologies based on solar or wind power. The project is also intended to draw on the results of the above research to establish a high performance microorganism type decontamination system industry, unexploited regional resource based river decontamination/small scale domestic wastewater treatment system industry, biomass sludge based resource conversion system industry, non-fossil clean energy powered decontamination system industry, and a monitoring and water environment improvement evaluation system industry, and to integrate and systematize all these technologies and new industries so that they function appropriately. In sum, the project is counted on to incorporate useful organisms that are not harmful to the environment in decontamination systems and to monitor the resulting water quality improvement in order to integrate creativity that develops environmental restoration technology that can be seen, the utility of guaranteeing fresh water resources, and the novelty of the comprehensive introduction of eco-engineering in order to establish water quality improvement systems incorporating eco-engineering. The project also has important roles to play by initiating substantial activities concerning treatment technologies intended to restore regional water environments, monitoring technologies, technologies, and forging close links between universities, national research institutes, the public, and regional public bodies in order to establish a Center of Excellence (COE) with the Kasumigaura Environment Research Center as its core institution. The goal is to apply the successful results of this development of advanced systems for use in domestic wastewater measures to contaminated lakes and marshes throughout Japan and around the world instead of limiting their application to a specific region, and in this way, develop a system that will contribute to the international community in order to make this area an information dissemination center that will become known as a lake and marsh conservation Mecca. Table 5 shows research themes of the Regional Concentration Type Joint Research Project. These concepts are not only applicable to lakes and marshes, but also applicable to inland harbor, inland sea, and river water.

Table 5 Research and development technology for joint research project of local concentration type

Developed technology	Subjects of deve;opment
Function strengthening system of advanced nitrogen and phosphorus removal functions of practically using useful microorganisms	•Development of methods of mass cultivation, sporing, and formulating usable advanced microorgnisms and evaluation methods by simulated ecosystem · Development of hybrid type advanced river and water channel purification system using advanced microorgnisms and physio-chemical methods and biopark purified resource type system · Development of pollutant load reduction technology for nitrogen and phosphorus by highly efficient multiple-stage purification system, practically using advanced microorgnisms
Development of polluted water improvement, bottom sediment improvement, and recycling technologies with ecological engineering employed	· Development of technology for improvement of bottom sediment, removal of water bloom and sludge regeneration and methods of directly purifying lakes by lean energy · Development of methods of strengthening of functions of sewage treatment plant by advanced microorgnisms, reduction of water bloom, sludge, and refuse, and practical use of compost
Comprehensive evaluation of water environment improvement effects and development of basic creating technology for methods of improving optimum treatment system	· Development of evaluation of effect for polluted water improvement by monitoring system of basin management · Development of evaluation methods by computer simulation to be applied on the effects of capital investment and energy investment

6 Future Problems and Prospects for Creating Sound Water Environments

Because water is the source of all life on the face of the earth and a common asset of the human race and all ecosystems, preserving water environments that can be used safely and with confidence for future generations is an important social mission and a responsibility that we must fulfill.

Both Japan and China share the same fear: namely that if present levels of domestic and industrial activities continue unchanged without any major modification of water quality preservation measures, eutrophication of closed water-bodies such as lakes, marshes, and inland harbors, pollution of rivers in urban regions, ground water contamination, and water pollution by trace chemicals will not only remain unresolved, but will in fact, become worse during the early years of the twenty-first century. It is forecast that in both countries, eutrophication will be accompanied by the spread of toxic algae in water source regions, trace chemicals will be discharged and be formed over wide areas, and that these processes will inevitably lead to potable water supply crises.

Considering such facts, eutrophication measures have been strengthened through measures such as the Law for Special Measures for the Preservation of Water Quality in Lakes and Marshes, but considering conditions in closed bodies of water whose quality has not improved, without a radical new approach, the problem will be difficult to resolve. Past environmental standards have only accounted for water quality, and water environment preservation measures have been based on principles of functional priority and achievement of standard values, but from now on, it will be necessary to make efforts to simultaneously improve water quality and create attractive urban districts accounting for the restoration of shoreline environments. In September 1995, the Environmental Agency proposed the Water Environment Vision that aims at the creation of overall desirable water environments including not only water quality, but water quantity, aquatic life, and the shorelines. This vision focuses on drainage basins and other water environment and emphasizes looking at them from the "perspective of place" and the "perspective of circulation" in order to create a desirable relationship between water and human beings.

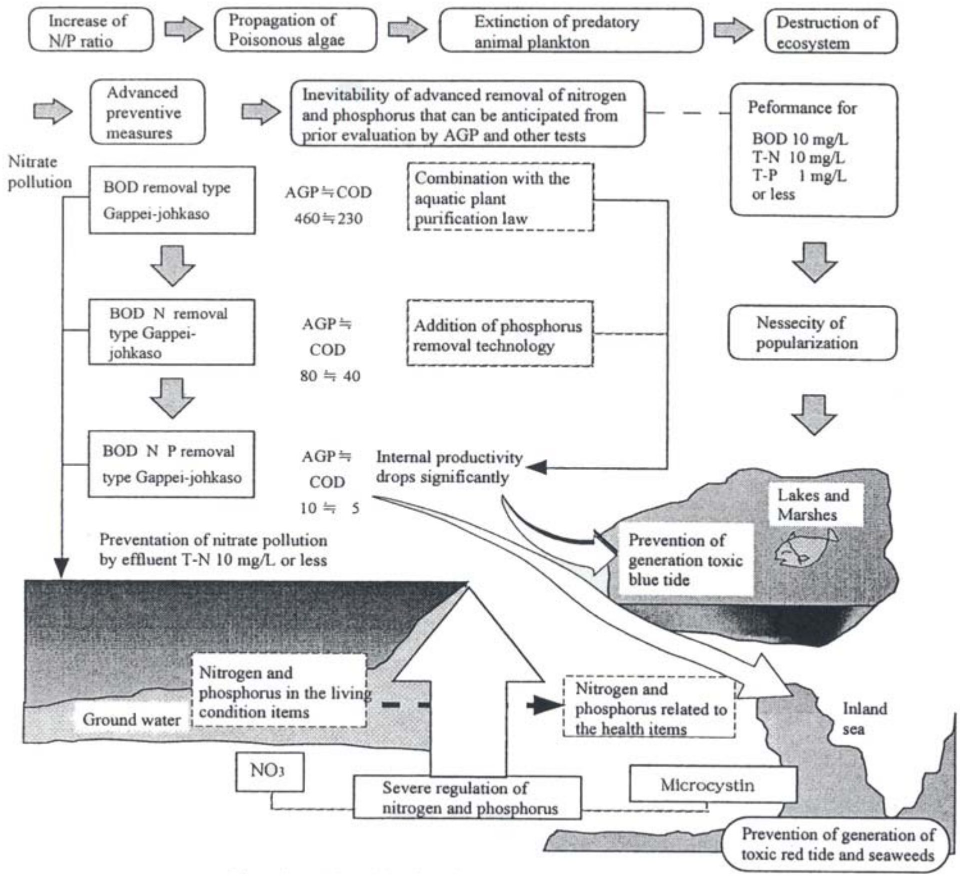


Fig. 6 Necessity of technical development for removal of nitrogen and phosphorus in measures against domestic wastewater

The foundations of the twenty-first century will be a socio-economic system in harmony with the environment, new technologies that make sophisticated use of bioengineering and ecoengineering will be developed, science and technology is sure to contribute to international society, the removal of nitrogen, phosphorus, and other nutrient salts will occupy an important place in domestic wastewater treatment measures, and advanced treatment technologies including advanced combined treatment domestic wastewater treatment tanks will play extremely important roles. The water quality improvement effects of the dissemination of nitrogen and phosphorus production source measures are schematically represented in Figure 6, but it will be essential to emphasize development from the perspective of environmental coexistence technology in order to preserve historical environments that minimize the load on the environment in this way, guarantee water ecosystems suitable for the creation of abundant natural environments, and integrate the natural environment with scenery that is harmonized with the natural environment. In the future, priority will be placed on the creation of cycle coexistence cities that will appear in the near future of the kind shown in Figure 7. And to resolve global environmental problems, it will also be necessary for Japan and China to cooperate with other nations in Asia and in other parts of the world in the task of developing and introducing water environment restoration technologies (Fig. 8).

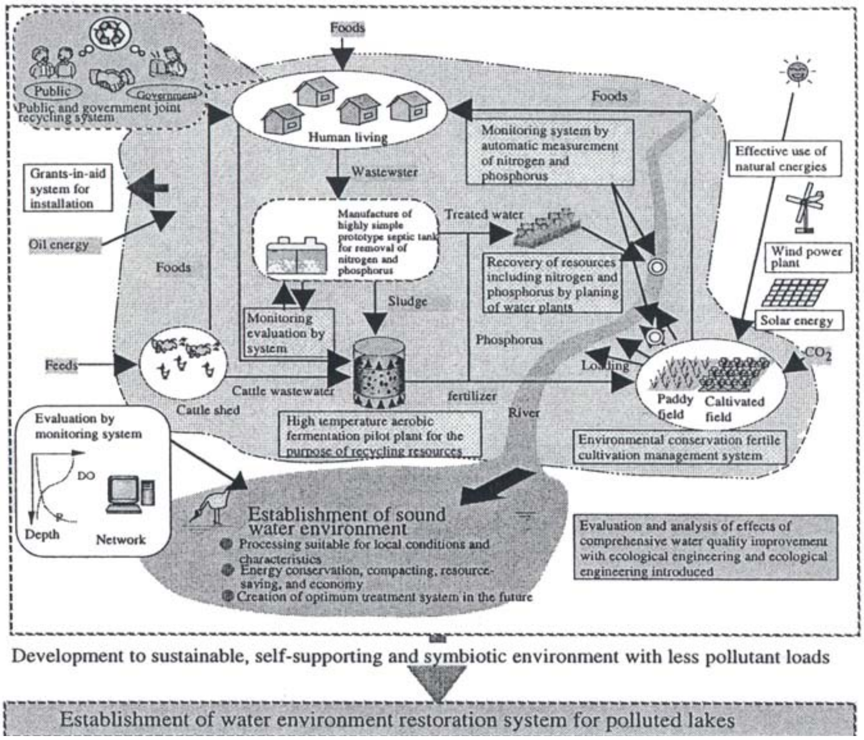


Fig. 7 Concept of constructing circulation symbiotic type local ecosystem

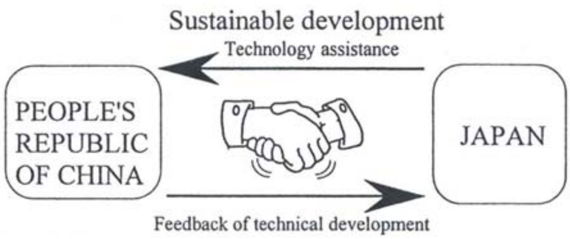


Fig.8 Technical cooperation with developing countries aimed at sustainable development of environment with less pollutant loads

7 Summary

The removal of nitrogen and phosphorus in effluent from domestic and industrial wastewater treatment facilities is most important to control the eutrophication. In this paper, new environmental problems caused by blue-green algae, necessity and improvement of nitrogen and phosphorus removal technology, and some advanced national projects were presented. As a cost-effective, energy-saving and less technique intensive innovation/alternative, ecotechnology and biotechnology may be more important and useful to water environmental conservation. Ecotechnology using wetland system, aquatic plant system, land treatment system, stream purification system, and some biological wastewater treatment systems should be established. The technical development for the removal of nitrogen and phosphorus by using the combination of ecotechnology and biotechnology, and the efficiency promoting for the biological water and wastewater treatment must be carried out to prevent eutrophication. Many studies, both science and engineering, are needed to develop an effective treatment system which provides suitable habitats of aquatic livings. Furthermore, the importance of international cooperative studies has been increased because the water pollution of international rivers and oceans become more serious problems and it is recognized that emission of green house effect gases from deteriorated water environment and wastewater treatment may cause global environmental problems.

To create and conserve the sound water environment, developed countries including Japan have a great responsibility to developing countries, and we believe that international cooperation among these countries would save our water environment.

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Eutrophication Prognosis and Realities for Lake Naivasha: Causes, Effects and Management Strategies

Mavuti K. M[1] ., N. Kitaka[2], and D.M. Harper[2]

1)Department of Zoology, University of Nairobi, P.O Box 30197 Nairobi, Kenya,

Tel/Fax 254-2-446141, Email: kmavuti@uonbi.ac.ke

2)Department of Zoology, Leicester University, Leicester, England

Abstract Lake Naivasha is the only freshwater (<5000 s/cm) Lake in Kenya's Rift Valley. The Lake is continually becoming more eutrophic due to environmental degradation and anthropogenic organic pollution and nutrient loading from intensive agricultural practices on the Aberdares and Kinangop catchments. Phytoplankton biomass shows a significant increase with time over the past decade. Some positive correlation between algae biomass, phosphorus and nitrogen dynamics have been discerned. There is overwhelming evidence of reduced Phytoplankton species diversity over the years which may be correlated with soluble reactive Phosphorus (PO_4–P) and soluble nitrates. It is predicted that with the current increase in population and agricultural practices, by the year 2010, the Lakes nutrient levels and eutrophic status will be more than trebled. The possible management solution would be rational management of agricultural land use.

Key-words Nutrient loading Eutrophication Environmental management

1 Introduction

Lake Naivasha is typical of an African shallow fresh water lake with marginal woodland savanna vegetation, fringed with papyrus swamp. It is located in the eastern rift valley of Kenya at 0.45‘N, 36.20‘E, 10‘S at an elevation of 1890 m above sea level. The basin has tectonic faulting and volcanic orientations which are associated with the rift valley formation. It lies in a topographically closed basin, but it is hydrologically a seepage, low sump, lake. Most of its surface waters input come from rivers Malewa, Gilgil and Karati (Fig. 1).

Lake Naivasha lies at the lowest sump in an endorrheic basin within an intensive agricultural region in the Rift Valley of Kenya. Agricultural and urban human activity contribute to basic changes in the lake catchment equilibria by accelerating trophic advance to a greater extent resulting in gradual eutrophication. This is not only detrimental to the well developed fishery in the lake but a major threat to the quality of the freshwater used for domestic purposes and livestock watering.

The Lake level and surface area fluctuates seasonally. Between 1990 and 1999 the Lake areal surfaces fluctuated between 140–152 km^2 a maximum depth of 11 m and an average of 5 m.

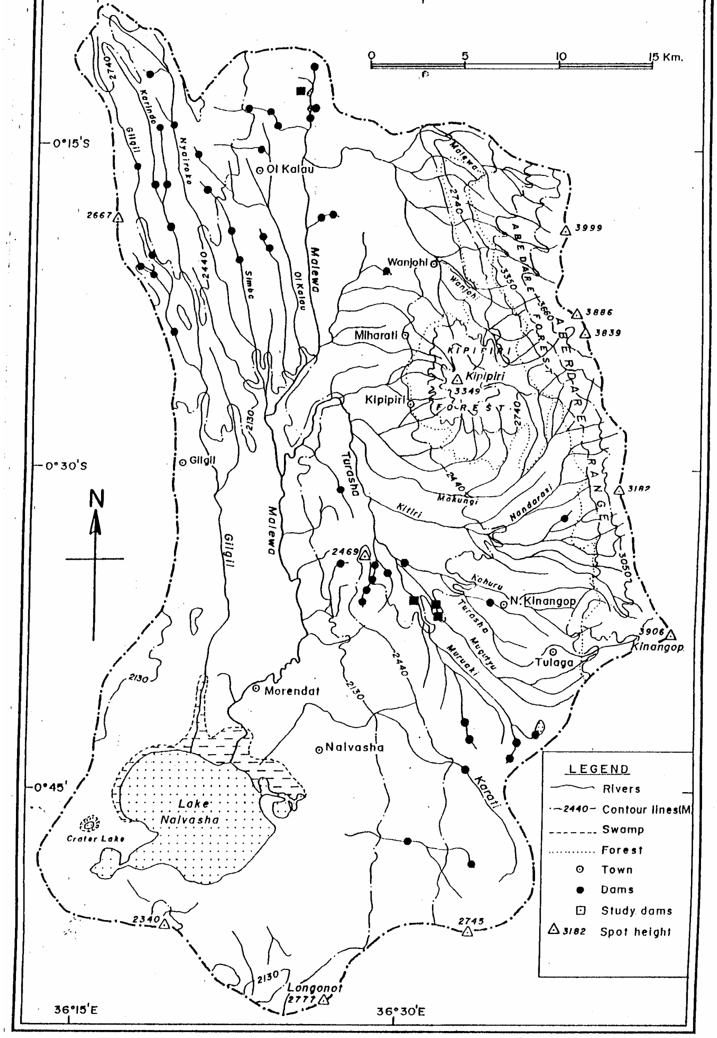

Fig. 1 Lake Naivasha water-shed and influent rivers

Due to its shallowness and gently sloping sides (Fig. 2), its surface area and that of the fringing papyrus swamps and littoral lagoons (Fig. 3) are very variable especially along the northern shore. There are extensive beds of submerged macrophytes i.e *Potamogeton octandrus* which dominated shallow waters below 1m depth, while *P. pectinatus* and *Najas pectinata* were abundant especially between 1–3 m depth (Fig. 4). Since the 1970’s the lake has been infested with a steadily increasing population of *Salvinia Molesta*. In the late 1980's, the lake has been further infested by the water hyacinth *Eichornia crassipes*.

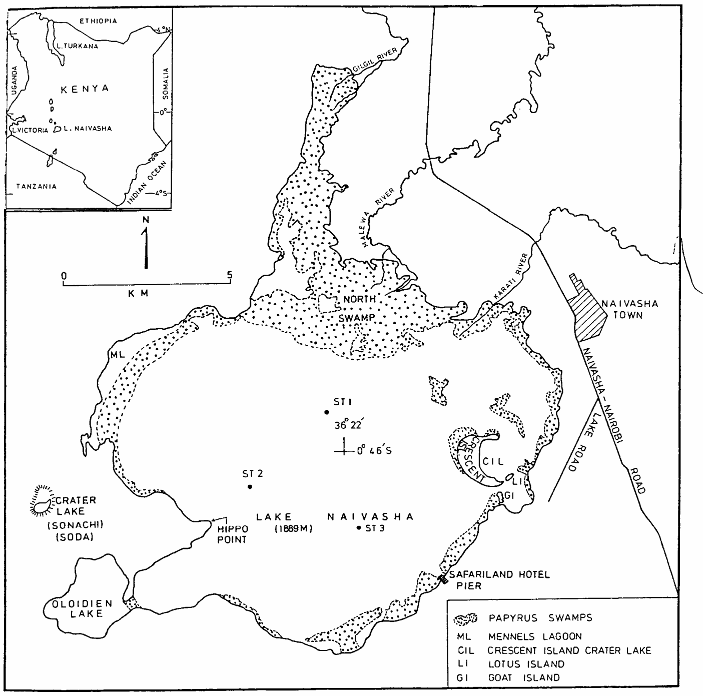

Fig. 2 Lake Naivasha ecosystem and associated swamps and lagoons

2 Methods

Over the past ten years, the littoral and limnetic ecological zones of the lake were sampled for various Limnological parameters: with a view to monitoring the nutrient status and water quality of the lake. Water temperature, dissolved oxygen, transparency as secchi depth, and conductivity were measured *in situ*. Vertical series of water samples for nutrient and algal analysis

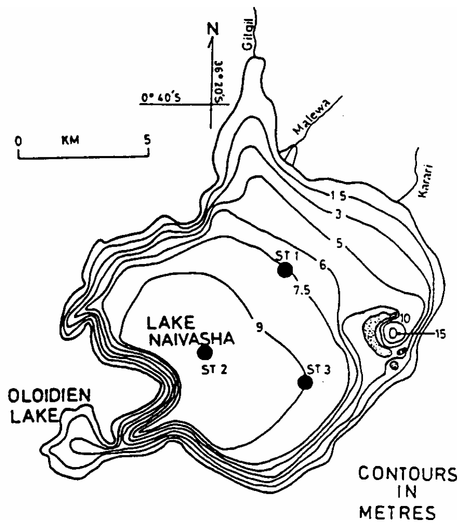

Fig. 3 Bathymetric contours of Lake Naivasha basin

were collected using a MacVuti volume sampler from the surface to bottom. Phytoplankton biomass was determined as chlorophyll a using 90% methanol for extraction method, after filtration through 0.45 Um Whatman GFC glass fibre. The filtered sub-samples were further analysed for nitrate, ammonia, and soluble reactive phosphorus. Total phosphorus was determined from unfiltered lake water by digesting the water samples with potassium persulphate and sulphuric acid (Mackereth *et al.*, 1978).

Algae cell counts were quantified from water samples collected using a phytoplankton net of 60 mm mesh hauled vertically through the water column and preserved in lugols solution. In addition routine assessment of catchment and urban land use activities were monitored throughout the study period.

3 Results and Discussion

Lake Naivasha water quality status has changed significantly towards increased eutrophication over the ten year period between 1990 and 1999.

As can be described from Table 1, generaly, Lake Naivasha water has characteristically high dissolved oxygen with a range of 6.66–8.84 mg O_2/L (76.8%–101.1% saturation), which indicates that the water was well oxygenated with high water temperatures ranging 19.6–22.6℃. This narrow temperature range over time agrees with Njuguna (1982) argument that temperature in tropical systems are sufficient enough to allow continuous organic production, both primary and secondary. During the same period, conductivity ranged between 222–481 ms/cm. The water turbidity is usually high as indicated by limited secchi visibilities of < 200 cm. The low transparency is mainly

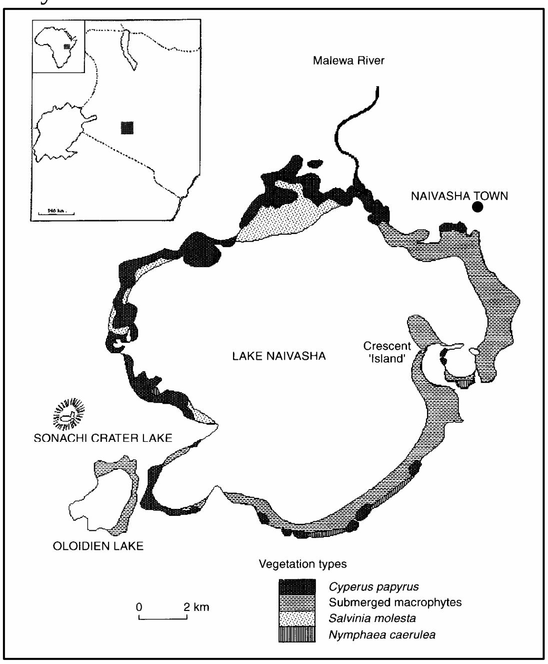

Fig. 4 The emergent and sub-mergent aquatic vegetation of Lake Naivasha (after Harper *et al*, 1998)

due to combined factors, i.e. influx of turbidsilt laden water from the catchment through river Malewa and the high phytoplankton abundance in both the littoral and open water areas.

Table 1 Mean values of Limno-Chemical factors of Lake Naivasha between January 1990 and September 1999

Time	Temp(℃)	DO(mgO_2/L)	OS(%)	ST(cm)	Cond(ms/cm)	DP(mg/L^{-1})	DN(mg/L^{-1})
January	22.5 ± 2.1	7.5 ± 2.0	99	85 ± 5	375	14 ±3	48 ± 3
February	22.6 ± 2.2	8.0 ± 2.3	93	92 ± 5	381	5 ± 3	37 ± 4
March	21.9 ± 1.9	8.8 ± 2.5	101	85 ± 6	482	19 ± 2	45 ± 4
April	22.2 ± 2.2	6.6 ± 2.1	76	82 ± 5	273	18 ± 2	27 ± 3
May	20.1 ± 2.3	6.8 ± 2.2	75	82 ± 5	260	21 ± 2	28 ± 2
June	19.9 ± 1.8	7.9 ± 2.0	87	85 ± 4	222	25 ± 2	25 ± 3
July	20.6 ± 1.9	6.8 ± 2.6	76	107 ± 5	330	18 ± 2	35 ± 3
August	20.3 ± 1.9	7.6 ± 2.4	84	117 ± 5	345	10 ± 3	56 ± 5
September	19.6 ± 1.0	8.2 ± 2.3	91	85 ± 6	452	36 ± 3	66 ± 6
October	22.6 ± 1.9	8.5 ± 2.4	100	82 ± 5	340	32 ± 3	80 ± 8
November	22.0 ± 1.8	8.6 ± 2.6	100	83 ± 4	320	35 ± 4	85 ± 6
December	22.2 ± 2.0	8.0 ± 3.6	99	84 ± 6	320	34 ± 2	50 ± 5

DO-Dissolved Oxygen; **OS**-Oxygen Saturation; **ST**-Section Transparency; **Cond**-Conductivity; **DP**- Dissolved Phosphorus; DN-Dissolved Nitrogen

4 Nutient Concentrations (Phosphorus and Nitrogen)

Algal growth and production in Lake Naivasha is basically and alternately limited by Nitrates and Phosphates but at various times of the year. Seasonal variation of Phosphorus in relation to nitrate, ammonium and chlorophlyll a was found to be significantly co-related. The values of soluble reactive phosphorus (PO_4–P) were low found to be in the open water but usually high in the Lake Littoral zone within the papyrus swamps and macrophytes between January–March. This coincided with higher chlorophyll a. followed by decline in the cool season until August when there was significant co-orelation between PO_4–P and chlorophyll a r = 0.461. The inference to make here is that it is likely that biological processes in the form of phytoplankton growth reduces the levels of PO_4–P in the water media (Biney 1990).

The increase in species richness results in increase in biological demand for (PO_4–P) thus making it a limiting factor to the existing phytoplankton population, subsequently resulting in decline in biomass.

Total phosphorus has been found to be very weak correlation with chlorophyll a (r = 0.13). This is because not all total phosphorus is available to phytoplankton because bacteria and fungi compete effectively with algae for phosphorus (Brylinsky and Mann 1973). But Talling (1966) postulated that estimating total phosphorus gives an indication of maximal or potential supply of the element irrespective of biological utilization. Therefore correlation between total phosphorus and chlorophyll a is not as strong in the tropics as that shown in the temperate lakes. This means that predictive models of total phosphorus to algal biomass used in relationship based on inter-lake comparisons in temperate lakes may not be adequate when used in tropical lakes (Kitaka 1991). Through out the years, however there is a clear trend towards increased Nutrient levels and subsequent increase in eutrophication.

Table 2 Concentrations of nutrients measured in Lake Naivasha water (L), and Malewa River (R), the main inflow to the lake. 1984–1990, from Harper *et al.*, 1993, 1995, 1999 from Kitaka (pers. com.)

Lake (L) — Year

Nutrient	1984	1988	1989	1990	1991	1995	1997	1999
DN	0-82	5-125	5-35	15-70	20-80	20-125	20-140	20-160
TN	400-600	100-475	300-675	300-685	200-500	300-800	300-850	200-850
DP	0-5	0-12	0-25	0-32	0-20	0-40	0-50	0-50
TP	50-90	50-73	50-200	8-64	10-100	10-150	50-300	50-400

River (R) — Year

Nutrient	1984	1988	1989	1990	1991	1995	1997	1999
DN	70	210	30	46	250	250	300	200
TN	425	1050	3000	2500	3000	2500	4500	3500
DP	11	32	40	37	50	30	60	50
TP	70	780	540	360	400	550	500	450

TN–Total Nitrogen; TP–Total Phosphorus; DP–Dissolved Phosphorus; DN–Dissolved Nitrogen.

Nitrate (NO_3–N) was higher between January and May which was then surfaced by ammonium (NH_4–N). Thus nitrates were positively correlated with chlorophyll a. As indicated earlier nitrates are alternately limiting nutrient in the lake. The high values of ammonium-nitrogen in the lake may be due to nitrogen fixation by the blue-green algae which occurred in high numbers to decomposition of organic matter in the sediments and which is transported upwards to the water media during everyday afternoon overturn (Melack 1979). The role of zooplankton and fish excretion in nutrient should not be overlooked (Mavuti 1990).

Table 3 Relative abundance of phytoplankton species in Lake Naivasha

Yanophyta	
Aphonocapsa delicatissima	+
Chrolococcus dispersus	+
Lyngbya contorta	+
Merismopidia tenuisima	+
Microcystis aeruginosa	4+
Oscillatoria	2+
Spirulina spp.	+
Chlorophyta	
Botryococcus braunii	2+
Chlamydomonus sp.	+
Closterium aciculea	5+
Closterium acutum	5+
Cosmarium sp.	+

Pediastrum boryanum	+
Pediastrum duplex	2+
Scenedesmus aciminatus	+
Staurastrum sp.	+
Tetraedron caudatum	+
Euglenophyta	
Euglena sp.	+
Trachelomonas spp.	+
Phacus spp.	+
Bacillariophyta	
Melosira ambigua	4+
Melosira granulata	4+
Navicula spp.	2+
Nitzchia spp.	3+
Synedra spp.	5+
Synedra ulna	4+
Synedra acus.	4+
Chrysophyta	
Chromulina sp.	+
Crysococcus sp.	+
Mallomonas sp.	+
Cryptophyceae	
Cryptomonus (reflexa)	+
Rhodomonas sp.	+
Dinophyceae	
Ceratium sp.	4+
Gymnodinium sp.	+
Peridinium sp.	3+

+ = Present/rare;
1+& 2+ =Common;
3+& 4+ = Abundance;
5+ = Dominant.

Diring this period, the inflowing rivers Malewa and Gilgil, entering the north of the lake are richer in total nutrients than lakewater, but similar in soluble concentrations Harper *et al.*, (1993), Table 2. Total nutrients are carried predominantly on silts and colloids which usually sediment or are filtered out by the papyrus swamp (Gaudet 1979). During the period of low water level and clearance of fringing vegetation, the inflow rivers entered the lake directly. During this period their influence on the lake chemistry is substantial.

Other surface inflows to the south and east of Naivasha are ephemeral and have an insignificant contribution. Single measurements of storm water runoff from agriculture, obtained occasionally, have yielded concentrations in tens of mg • L^{-1} soluble nitrogen and phosphorus but these storm runoffs usually soak away without reaching the lake Harper *et al.*, (1993). The only point source of nutrients is from the Naivasha town sewage treatment plant, which has tertiary treatment oxidizing ponds and also produces an effluent which does not reach the lake.

Evidence so far shows that during the rainy season, the flush floods and increased discharge from the agricultural catchments increase nutrient concentration whilst at the same time, diluting the lake water. This nutrient loading has been increasing over the years due to increased subssistance agricultural land use in the upper catchment and commercial floriculture in the immidiate plains, South East, and South West of the lake. During periods of draught, the lake level falls even below the 1986 meters asl. When this happens, the buffering effect of papyrus is lost, dissolved salts nutrients and algae biomass build up in the lake water as a direct river flow as well as evaporative concentration.

5 Phytoplankton Composition

The species diversity of the phytoplankton fluctuated seasonally and inter-annually. Chlorophyta was the most common, consisting of order chlorococales. The most dominant genera was *pediastrum spp*, where three species were encountered, *P. Simplex*, *P. duplex* and *P. tetras*, *Anicistrodesmus spp*, i.e *A. fusiformis*, *A. gracilis and A. falcatus*, *Scenedesmus* with major species *S. acuminatus* and S. *quadricauda*. The order *Zygenematales* was represented by 3 genera, *Closterium*, *Cosmarium sp*. and *Staurastrum spp.* Two species were encountered *S. tetracerum* and *S. paradoxum*. When compared to the freshwater lakes in the other lake region the species diversity was very low reflecting a gradually eutrophicating ecosystem.

The most prevalent genera found in Lake Naivasha included genera *Closterium*, *Melosira* and *Microcystis* (Table 2). *Closterium sp* dominated in the cooler and wetter months between January to July. Between September and December these were usually replaced by *Melosira* spp. mainly *M. italica*, and *M. ambigua* (Grun) O. Muller, *Microcystis* sp. and *Ceratium* sp.

The composition structure was much like one observed by Njuguna (1982) and Mavuti (1983) when the lake level was high but rich in nutrients. Other earlier studies in the Century showed that phytoplankton in Naivasha was dominated by diatoms in 1931 (Beadle 1932), desmids in 1964 (Lind 1967, 1968) and Blue-green algae (Kallquist 1979). These were years when the lake was supposedly prestine.

6 Conclusions

When all is considered the intensive floriculture and its concomitant use of fertilizers which dominate nearly one third of the immediate land use, is a major threat to the lakes water quality status. Indeed the upper catchment has seen in the last ten (10) years a ten fold increase in human and livestock population with the attendant land degradation. The small holder farms and water harvesting activities have had a profound effect on the hydrological balance into the lake. Equally the increase in usage of fertilizer and sewege runoff into the lake predicts a grave situation for the lake and its biota. The lake has seen invasive weeds developing and covering the water surface almost totally. In particular the *Salvenia molesta* and *Eichornia crassippes* have been the most tell tale nuisance water weeds throughout the 10 years of gradual degradation and Eutrophication of Lake Naivasha. Major changes have occurred this decade in the species and distribution of fringing euhydrophyte beds and in the biomass of phytoplankton (Harper 1992). Explanations for these changes are based upon the consequences of alien introductions and the effects of water level fluctuations combined with intensive lakeside agricultural development (Harper, Mavuti & Muchiri 1991).

Acknowledgements

This paper is a very short summary of a broader research project on nutrient loading and dynamics into Lake Naivasha undertaken between the University of Nairobi and the Leicester University, U.K. over the past decade. We would like to thank the Earthwatch Watertown, Boston USA for financial support for this work. We would also like to thank the Chinese Research Academy of Environmental Sciences for their kind invitation and financial support to K. Mavuti to the Symposium on Lake Eutrophication in Dali City, China.

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Estimation of Oxygen Budget in Polluted Aquatic System

Ju-Chang Huang   Guanghao Chen

Hong Kong University of Science & Technology, Hong Kong, China

Abstract One of the most damaging effects of eutrophication is the high fluctuations of dissolved oxygen due to photosynthetic and respiration activities. In many cases, severe deficiency of D.O. may occur, particularly in the summer night. To safeguard the fish life and also to prevent the problem of nuisance odors, it is important to make an accurate estimate of the critical oxygen deficit in an eutrophicated aquatic system, so that proper engineering actions can be taken to reverse the oxygen deficiency problem. In this study, a proper method for estimating the oxygen budget in Hong Kong's Shing-Mun River (a tidal aquatic system) was developed based on the carbonaceous oxygen uptake, algal photosynthesis and respiration, sediment oxygen uptake, as well as the oxygen supply from surface aeration and tidal recharge. A systematic study was conducted to examine the effect of temperature, flow velocity and water depth on both the oxygen inputs and consumptions. The results of this study have shown that at a water temperature of around 10℃ (the lowest temperature in the river), no oxygen deficit occurs. When water temperature was 10–20℃, a small oxygen deficit appeared, especially in the deeper water. As the water temperature reached 30℃ in the summer time, the oxygen deficit could reach as much as 6.84g $O_2/m^2/d$ at night during the Spring tide period.

Key-words Lake eutrophication   Estimation of oxygen deficit

1 Introdcution

The Shing Mun River is a tidal river in Hong Kong which has received considerable pollution discharges from both domestic and industrial sources in the last two decades. Odor nuisance has been a serious problem due to severe oxygen deficit in summer months. One alternative to rectify such a problem is to apply the lake aeration/circulation technology to increase its oxygen supply (1). Such a technology can greatly increase the oxygen supply at a low energy cost without creating an undue water turbulence in the aquatic body. It involves placing air diffuser plates at the river bottom to discharge fine air bubbles (about 140 microns), thereby creating a gentle-moving water plume, much similar to that observed in a water spring. The moving plume will bring the oxygen-poor bottom water to the surface with gentle ripples (Fig. 1) which will greatly increase the oxygen transfer efficiency. In some cases, the oxygen transfer rate can reach as high as 3-5 kg/hp-hr, depending on proper water depths, as opposed to the normal 0.7 kg/hp-hr observed in conventional wastewater treatment system (2). The lake aeration/circulation technology has been proven to be one of the most cost-effective approaches in improving water quality (2,3). In order to estimate the capital and operational costs in applying such a system, the critical oxygen deficit under the worst condition must be first determined.

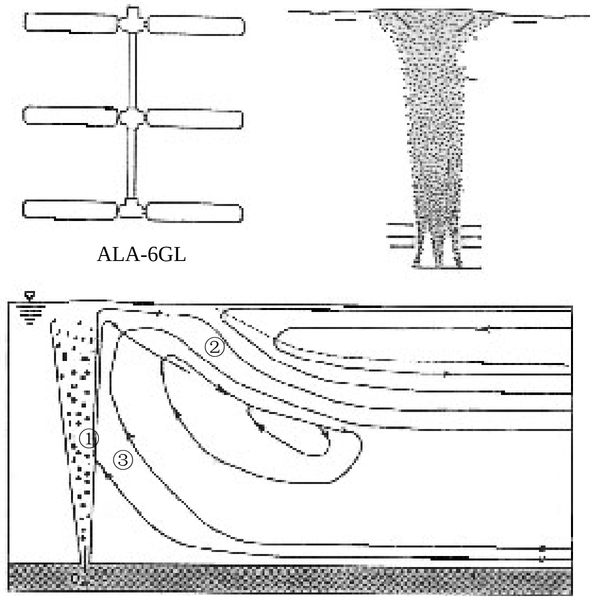

Fig. 1 A schematic illustrating lake aeration/circulation technology

This study was carried out to identify the critical oxygen deficit that could occur in Shing-Mum River by evaluating its oxygen budget based on both oxygen demands and oxygen supplies. More specifically, it involved a systematic study to evaluate: i) oxygen uptake rate in main water; ii) oxygen uptake rate by algal respiration; iii) oxygen uptake rate by sediment; iv) oxygen supply rate through surface aeration; and v) oxygen supply rate by algal photosynthesis.

2 Hydraulic Features and Field Sampling

The Shing-Mun River is a 7-km tidal river. Its main stretch is 162-meter wide and 4-kilometer long. Since it is a tidal river, its flow velocity and water depths change with tides. In general, the average flow velocity is 0.16 m/s during Neap tide and 0.26 during Spring tide. The corresponding water depths in the river are 1.6 and 2.2 m. In conducting field samplings and in-situ investigations, a 315-m river stretch was selected in this study. The river’s bottom has accumulated variable depths of mud, up to 2.65 m at the center of the channel. Three sampling locations across the 162-m width were chosen in the selected stretch.

3 Estimation of Oxygen Demands

3.1 Carbonaceous Oxygen Consumption in Water Body

In the water body, suspended microorganisms oxidize carbonaceous organic matter and in doing so, oxygen is consumed. This is called “carbonaceous oxygen demand”, and its rate can be described as follows (3,4):

$$\frac{dC}{dt} = -K_{1,20}\ \theta_w^{\ T-20} S_b \tag{1}$$

Where, C—the DO level in water (mg/L);

$K_{1,20}$—the specific oxygen uptake rate at 20℃ (day^{-1});

S_b—the concentration of organic matter (mg BOD_5/L);

T—the water temperature (℃);

θ_w—the temperature coefficient for microbial activities, usually taken as 1.05 (3). A typical value of the $K_{1,20}$—0.1–0.2 d^{-1} (3). In this study, it was assumed to be 0.1 d^{-1} (4).

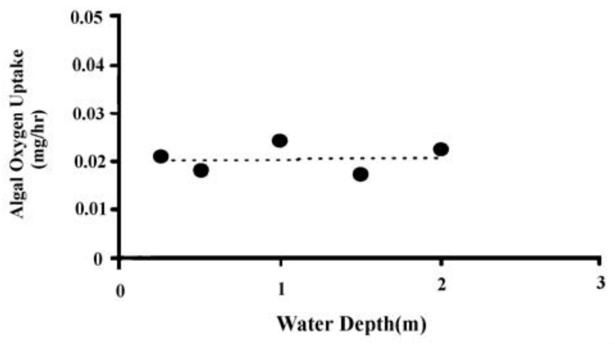

Fig. 2 Algal oxygen uptake rates at different water depths

3.2 Oxygen Uptake by Algae

Algal respiration in the absence of sunlight consumes a significant amount of dissolved oxygen. Its rate is mainly influenced by water temperature, which may vary with water depth. Thus, it is necessary to examine the effect of water depth on the algal respiration rate. In this study, a "light" and "dark" bottle method (5) was used to evaluate algal oxygen uptake rates at different water depths. The "light" bottle was to allow light penetration while the "dark" bottle (wrapped with aluminum foil) was to simulate the evening condition. In both cases, the standard BOD bottles were employed in the measurement. The bottles were installed at the desired water levels to let them exposed to the real light intensity and temperature in the field. Figure 2 shows that the oxygen uptake rate was independent of the water depth since there was no significant temperature variations at different depths (only 0.4℃ difference from the surface to the bottom). The air temperature varied from 12℃ to 14℃ during the field testing.

The overall oxygen uptake rate can be expressed as:

$$\left(\frac{dC}{dt}\right)_{overall} = -K_{2,13} S_a - K_{1,13} S_b \tag{2}$$

Where, S_a—the algal concentration (mg dry wt./L) and S_b—the BOD_5 concentration (mg/L). The mean values of the S_a and the S_b had been found to be 1.5 mg dry wt/L and 9 mg/L, respectively (1). Based on Eqs. (1) and (2), the $K_{2,13}$ (algal respiration rate at 13℃) can then be determined:

$$K_{2,13} = \frac{-\left[\left(\frac{dC}{dt}\right)_{overall} + K_{1,13}S_b\right]}{S_a} = \frac{-(-0.02/0.33\times 24 + 0.1\times 1.05^{13-20}\times 9)}{1.5} = 0.54 \qquad (3)$$

3.3 Oxygen Uptake by Bottom Sediment

Sediment core samples were taken from the river using a hand-sampler equipped with a removable PVC tube of 5-cm in diameter and 100 cm in length. Through this operation, sediment samples obtained from different depths could be separated for measuring the oxygen demand.

A bench-scale sediment oxygen uptake (SOU) measurement system was developed (Fig. 3). This system has an acrylic rectangular chamber having a volume of 2.9 L. Three perforated baffles were installed to create a uniform flow in the chamber. A pump was used to circulate the water at any desired flow rate. Three sub-samples, each 5-cm thick and taken from the top sediment layer, were placed in the chamber, as shown in Figure 3. The average solids content of the three samples was found to be 787.3 mg dry wt./cm^3. In this SOU measurement system, the total water-sediment contact area was 71.3 cm^2. The total volume of the system including the circulation piping was 6 L. Continuous recirculation was carried out in an environmental chamber regulated 11℃, 18℃, 27℃, and 35℃, respectively. The flow velocity at the sediment surface, called “shear flow velocity”, was determined by a laser flow velocity meter. The velocities were found to be 0.035, 0.053, 0.076, 0.089, and 0.104 m/s, respectively, at circulation flow rates of 6, 8, 10, and 12, and 14.5 L/min. The overlying water was the filtered river water and the whole test system was kept air tight. In each test, the DO level was continuously monitored and the initial and the final concentrations of COD in the overlying water were also measured (9).

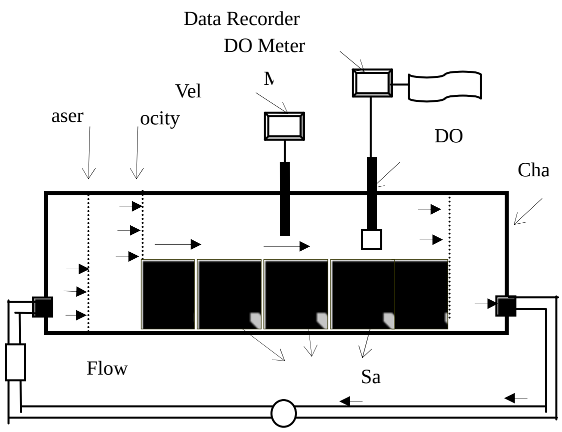

Fig. 3 Experimental setup for measuring sediment oxygen demand

Table 1 shows the effect of flow velocity and water temperature on the rate of sediment oxygen uptake. It was found that both the flow velocity and water temperature affected the uptake rate, particularly the latter. This is because a higher water temperature greatly accelerated the bio-oxidation activity in the sediment, and its impact was much greater than that induced by the shear velocity (4). Through mathematical regression, the following equation was developed to predict the effect of both the shear velocity and the water temperature on the sediment oxygen uptake rate ($K_{3,T}$, g O_2/m^2/d) under the conditions that the water temperature was between 11℃and 35℃ and the flow velocity from 0.035 to 0.104 m/s:

$$K_{3,T} = 9.96 \times U_s \times 1.079^T \tag{4}$$

Where, U_s—the shear flow velocity at the sediment surface (m/s). If the flow velocity profile along the water depth follows a logarithmic distribution, then

U_s—the river can be determined (1) by:

$$U_s = 1.63(\frac{H_s}{H_m})^{0.5} U_m \tag{5}$$

Table 1 Sediment oxygen uptake rates at different shear flow velocities and water temperatures

Shear flow velocity (m/s)	Sediment oxygen uptake rate (g O_2/m^2/d)			
	11 °C	18 °C	27 °C	35 °C
0.035	0.92	1.66	4.27	5.86
0.053	1.1	1.82	4.5	11.48
0.089	1.69	3.24	5.17	12.7
0.104	2.17	5.14	8.47	14.07

Where, H_s—the thickness of the shear layer above the sediment (m);

H_m —the mean water depth of the river (m); and

U_m —the mean river flow velocity (m/s).

4 Estimation of Oxygen Enrichment

A. Oxygen Supply from Surface Reaeration

In a river, the oxygen input rate by surface reaeration can be expressed by:

$$\frac{dC}{dt} = K_L(C_s - C) \tag{6}$$

Where, K_L —the reaeration coefficient (d^{-1}); and

C_s —the saturation concentration of DO (mg/L). The K_L can be calculated by the following equation (6):

$$K_L = \frac{[\frac{D_{wc}(giH)^{0.5}}{\kappa} H]^{0.5}}{H} \tag{7}$$

Where, D_{wc}—the diffusivity of oxygen in water, cm^2/d;

g—the acceleration of gravity,m/s^2;

H—the water depth, m;

i—the hydraulic gradient of the river; and

κ—the Karman constant. It was found (1) that D_{wc} = 1.6 cm^2/d, i=0.8/10,000 for the Shing-Mun River, and κ = 0.4. With these values, Eq. (7) can then be simplified as:

$$K_L = 0.984 H^{-1.25} \qquad (8)$$

4.2 Oxygen Supply from Algal Photosynthesis

Photosynthetic activity of algae in any river is significantly influenced by sunlight intensity, algal concentration and water temperature. It is known that in the Shing-Mun River the sunlight intensity and the algal concentration decreased with water depth while temperature was not affected by water depth (1). To quantitatively correlate the water depth with the algal oxygenation rate (K_4), a set of "light" and "dark" bottles were installed at different water depths on July 9th of 1997. The oxygen oxygenation rate by algal photosynthesis at 25℃ in the "light" bottles were estermined. Figure 4 shows the variations of the photosynthetic production at different water depths. It was found that the oxygenation rate became zero when the water depth was greater than 1.5m. This was because very little sunlight could penetrate through this water depth. Actually the Secchi transparency was observed to be around 110 cm and suspended solids was found to be 18–37 mg/L in the river.

On that particular day, the average sunlight intensity was found to be 25,000 lux (1). The specific oxygenation rate (d^{-1}) was calculated from the data of Figure 4, together with the bottle volume (330 ml), algal concentration (1.5 mg dry wt./L), and a 12-hour lighting period. This oxygenation rate was then correlated with the water depth as follows:

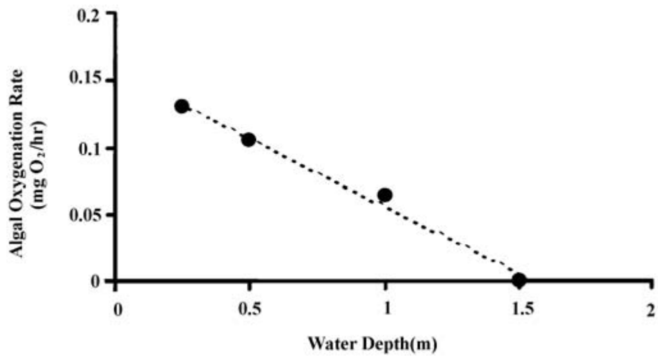

Fig. 4 Algal oxygenation rates at different water depths

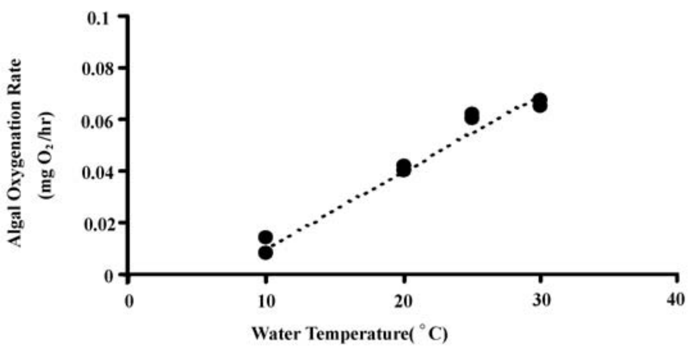

Fig.5 Effect of temperature on algal oxygenation rate

$$K_{4,25} = -2.54H + 3.88 \tag{9}$$

In order to determine the effect of water temperature on the algal oxygenation rate, composite samples were made by taking river water at different depths. The samples were used to measure the oxygenation rates at 10℃, 20℃, 25℃ and 30℃ respectively in the laboratory. The tests were conducted at a light intensity of 6,300 lux for 12 hours. Figure 5 shows the results of the temperature effect on the oxygenation rate.

This figure can be used to develop an equation to predict the specific rate of the algal oxygenation rater at different water temperatures, as shown below:

$$K_{4,T} = 0.069T - 0.4 \tag{10}$$

To compare Eq. (10) with Eq. (9) for the same light intensity, it must be pointed out that it has been assumed that the algal oxygenation rate is directly proportional to the sunlight intensity up to 6,300 lux. However, our lab tests showed that at this light intensity the algal photosynthesis was actually somewhat inhibited (10). Thus, the right-hand side of Eq (9) should be divided by 4 (i.e., 25,000/63,000), and this yields:

$$K_{4,25} = -0.636H + 0.97 \tag{11}$$

When H=0 , T=25℃, and light intensity =6,300 lux, the predictions of the $K_{4,25}$ by both Eqs. (10) and (11) become fairly consistent. Therefore, Eq. (10) would be corrected as:

$$K_{4,T} = 0.04T \tag{12}$$

Based on Eqs. (9) and (12), an overall equation for predicting the algal oxygenation rate at different water temperatures and depths can be developed:

$$K_{4,T} = (-2.54H + 3.88) \times 0.04T \tag{13}$$

5 Oxygen Budget Calculations

With the above results, the oxygen budget (ΔDO) in every square meter of water column can be calculated as follows:

$$\begin{aligned}
\Delta\mathrm{DO}\ (\mathrm{g/m^2/d}) = & +\left[(-2.54H_{pm} + 3.88) \times 0.04T \times H_m S_a\right] && \text{Algal oxygenation at daytime only} \\
& +\left[0.984 H_m^{-1.25} (C_s - C) H_m\right] && \text{River surface reaeration} \\
& -\left[0.1 \times 1.05^{T-20} H_m S_b\right] && \text{Oxygen uptake by water} \\
& -\left[0.39 \times 1.05^{T-20} H_m S_a\right] && \text{Oxygen uptake by algal respiration at nighttime only} \\
& -\left[9.66 U_s 1.079^{T}\right] && \text{Oxygen uptake by sediment}
\end{aligned} \tag{14}$$

Where, H_{pm} —the mean water depth for photosynthesis (m). If H_m >1.5 m, H_{pm} =0.75 m; if H_m <1.5 m, H_{pm} =H/2. S_b —BOD_5, 9 mg/L;

S_a —the algal concentration, 1.5 mg dry wt/L; C_s —the actual D.O. It was assumed that C were 8 mg/L, 7 mg/L, 6 mg/L, respectively, at 10℃, 20℃, 30℃ during daytime, and 4 mg/L, 3 mg/L, 2 mg/L during the nighttime. The C_s values at different water temperatures were calculated by the following formula for seawater (7):

$$C_s = (14.16 - 0.3948T + 0.007714T^2 - 0.0000646T^3) \times 0.9 \qquad (15)$$

U_m and H_m of both the Spring and the Neap tides were estimated from hydraulic simulation, as indicated in Table 1. U_s was then calculated by Eq. (5) under an assumption of H_s at 0.05 m.

In the calculation of oxygen budget using Eq. (13), both daytime and nighttime is assumed to be 12 hours. In the daytime calculation, algal oxygenation rate is calculated by the first term of the right hand side in Eq. (13) for 12 hours while the fourth term for algal oxygen rate is zero. In the nighttime calculation, the first term then becomes zero while the fourth term is used to determine the algal oxygen uptake rate. Thus, the oxygen budget (ΔDO) in a 1-m^2 water column of the Shing-Mun River in both daytime and nighttime can be determined by Eq. (13) with different water depths and temperatures. The determinations at 10℃, 20℃, and 30℃ are shown in Figure 6. At the lowest temperature of 10℃, the oxygen budget is a surplus in both nighttime and daytime. Such a low temperature favors surface reaeration and it produces more oxygen than that consumed by algal respiration, sediment oxygen uptake, and carbonaceous oxidation. When the temperature rises to 20℃, both the oxygen demands and algal oxygenation increase but the oxygen supply rate is slightly less than the total demand rate. As a result, the oxygen budget becomes a small deficit along the depth of the river, even in the daytime. The extent of deficit becomes more profound in the nighttime as there is no algal photosynthesis. When the water temperature further increases to 30℃, which is the highest temperature expected for Shing-Mun river, whether it is in the daytime or in the nighttime, the oxygen budget shows a great deficit over the entire cross-section of the river. This deficit eventually reaches a maximum of 6.84 g $O_2/m^2/d$ in the nighttime during the Spring tide.

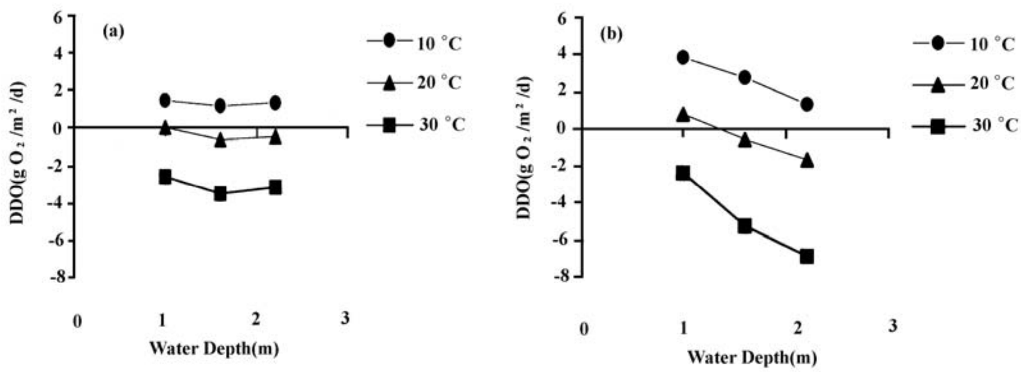

Fig. 6 Oxygen budget at different water depths and temperatures (a= day time; b= nigh time)

It should be noted that the ΔDO only reflects the oxygen budget at a stationary state of the river water, which is different from that of real situation. However, it is still useful for an engineer to identify such a critical ΔDO at a stationary state so that he is able to estimate the total amount of oxygen that needs to be put into the river system and the associated capital and operation costs.

6 Conclusions

A systematic study of the oxygen demands and supplies in the Shing-Mun River has been conducted through both in-situ and lab investigations. From the observed data, the following conclusions can be drawn:

（1）The oxygen uptake rate by algae was independent of water depth, which was found to be 0.39 d^{-1} at 20℃.

（2）The mean concentration of algae in the river was estimated to be 1.5 mg dry wt./L. The prevalent algal species were Amphora sp, Cyclotella sp., Oscillatoria sp., and Chlorella sp.

（3）The sediment oxygen uptake was more affected by water temperature than by the flow velocity. The following equation was developed to address the effects of temperature and water depths for a flow velocity between 0.035 m/s and 0.104 m/s:

$$K_{3,T} = 9.96 \times U_s \times 1.079^T$$

（4）The algal oxygenation rate was found to follow the following equation:

$$K_{4,T} = (-2.54H + 3.88) \times 0.04T$$

The maximum oxygen deficit in Shing Mun river is estimated to be 6.84 g $O_2/m^2/d$, which occurred at 30 ^oC in the nighttime during a Spring tide period.

Acknowledgements

The authors would like to acknowledge the financial support of the Shatin District Board of HKSAR. Most of the field and lab work were carried by two research assistants, J. Liu and I.M. Leong. Other technical assistance was also provided by Drs. Qian P. Y. and Zhang Y., both of the Biology Department of the Hong Kong University of Science and Technology.

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Countermeasures for Eutrophication Control of Taihu Lake

Wang Xiaorong Guo Hongyan

State Key Laboratory of Pollution Control and Resource Reuse

School of the Environment, Nanjing University, Nanjing, China

Abstract The eutrophication of waterbody in Taihu Lake has seriously influenced the sustainable development of whole basin .Recent reports from various publications in China indicate that eutrophication and ecological destruction in the region is caused mainly by intensive human activity. The eutrophication in the lake and its causes are presented and controlling measures over eutrophication of Taihu Lake are discussed in detail in this paper. To restore Taihu Lake from eutrophication, it is necessary to take the following actions: reducing the release of nutrient from external and inner source, strict management, remediation of the ecosystem step by step, and establishing the prediction model based on occurring mechanism of algae bloom. it is of the same importance to find new methods to directly control algae bloom , which can reduce the loss caused by algae bloom greatly.

Key-words Taihu Lake Eutrophication Control

Located in the Yangtze Delta of East China, Taihu Lake is one of the five famous great fresh water lakes in China, with an area of 2,428 km^2. It is the main water sources for Shanghai, Suzhou, Wuxi etc.. and possesses several functions, including water supply, floodwater store, irrigation, shipping, breeding aquatics, tourism etc. Highly developed in its economy , Taihu Lake basin is one of the most densely populated and urbanized areas in China, with a total of 35.98 million people and 38 cities in the surrounding area of 36,500 km^2 .Recently, its eutrophication is becoming more and more serious and it greatly affected the social and economic sustainable development of whole basin. Therefore, it’s urgent for us to solve the problem of eutrophication to protect Taihu Lake.

1 Present Situation and Causes of Eutrophication in Taihu Lake

Eutrophication of Taihu Lake is becoming more and more serious recently due to speedy development of local economy. The concentration of Total phosphorus(TP) and Total nitrogen(TN) in lake water surpasses that stipulated in Standards greatly. Natural observation of eutrophication is listed as following: the transparence of lake water decrease visibly, biodiversity is reduced, algae bloom occurs more frequently and the occurring area is becoming larger and larger in warm seasons. The algae bloom ,which broke out in July 2000 ,is the severest one since 1980,covering most area of Taihu Lake, including Gonghu, Meilianghu, Wulihu etc. The inlet water transparence of Gonghu was zero. Since the beginning of 1980, the level of eutrophication has increased by two grades from middle-eutrophication to heavy eutrophication. Among 24 monitored sites, 37 percent have been polluted, among which 46 percent are in the state of mid-eutrophication and 54 percent in the state of eutrophication. The input amount of TN, TP and TOC is 8.8, 33.2, 3.76 times as high as the maximum capacity of Taihu Lake respectively[1]. The nutrient input from external source and release from sediment together with the destroy of ecosystem cause the formation of eutrophication in Taihu Lake.

Taihu Lake Basin is one of the four urbanized areas in China. The discharge amount of waste water from the cities is about 43 billion tons, (not including the towns in the area). The proportion of domestic sewage is increasing recently, nearly 80 percent discharged without any treatment. Remove of TN and TP from industrial wastewater was not considered for a long time. The wastewater discharged from the cities contributes to Taihu Lake as an important source of nitrate and phosphorus.

Taihu Lake drainage area is the agricultural developed region in China. Non-point source pollution from farming activity is the main contribution of nitrogen and phosphorus. In the report handed to congress by USEPA, the land loss of nutrient is the main reason which cause eutrophication of inland lake[2]. In Taihu Lake, the proportion of the nutrient from non-point source pollution is about 50 percent. However, there is no good methods available at present to control such losses to Taihu Lake.

Taihu basin is one of the most densely populated area and human activities harm the ecosystem seriously, such as purse seine, breeding aquatics, excessive catching etc. together with the overloading of pollution, which cause the increase of pollution-tolerable zooplankton, decreasing of some kinds of fish, degeneration of hydrophyte[3],which possess the function of restraining storm, accelerating sedimentation, stabilization of sediment, maintaining the quality of the water[4,5]. However, the self-adjust ability of water body was lost due to large reduction of the hydrophyte, which make the suspending and releasing of phosphorus from sediment much easier. The above mentioned factors make the eutrophiction of the lake more and more serious and subsequently promote algae bloom occur almost every year.

2 Countermeasures for Eutrophication Control

2.1 Control the nutrient salt and pollution load into Taihu Lake

Point sources control Required in the ‘ninth five year plan’ and ‘ programming of water pollution control in Taihu Lake in 2010’, 96 waste water treatment plants should be founded before 2000y with the treating capacity of 3.868 billion tons per day. But due to fund shortage, it is very difficult to achieve the goal. With the rapid development of villages and local enterprises, more and more people are living in towns. Much waste water is discharged into environment because there is no water treatment plant in most towns. However, It is impossible to resolve the problem in the ways adopted by treatment of municipal wastewater. So it is urgent to research on such wastewater treatment technology of high efficiency, low cost that it is accepted by local people under the

Chinese present economic situation. Only in this way, can point sources pollution be controlled effectively.

Non-point source pollution control To boost agricultural crop production to a high level in Taihu Basin, the fertilizer input to land increase very quickly. According to the statistics, the proportion of non-point source pollution(NSP) caused by fertilizer and pesticide is nearly 50 percent among total input into Taihu Lake. Therefore, NSP is a main source which should be considered mainly for controlling the eutrophication of Taihu. But it is more difficult to be controlled than point source pollution for its complex sources, changing amount and the large area. In China, there is no example by now that NSP is controlled successfully**.** In order to solve the problem, the following research should be conducted: the study on the rule of the nutrients' quantitative transport into lake, establishing the nutrient prediction model, by which scientific regulations can be made and effective management can be carried out. Furthermore, it is necessary to choose some typical villages and towns as an example to study treatment on NSP, from which experience and knowledge obtained is essential to the successful control of all area.

2.2 Study on the inner source pollution and nutrient released from sediment

29 percent bottom of Taihu Lake is covered by thick sediment with depth of more than 0.1m and about total 6.91billion m^3 sludge is estimated in Taihu. The release of nutrient like phosphorus from sediment and the suspending of sediment is very active[6]. Phosphorus is the limiting factor on growth of algae in Taihu[7]. Therefore, it is impossible to control effectively the eutrophiction in Taihu only through controlling the external sources for the released nutrients, as the inner sources are still sufficient in the eutrophication state of Taihu for a long period of time. As a result, it is very important to research the recycle of nutrient, especially the release of phosphorus in sediment [8] .

The release of nutrient from sediment is a complicated process, including physical, chemical and biological process[9]. Sedimentation rates were determined by ^{210} Pb dating methods in Taihu .The phosphorus fluxes in sedimentary cores from Taihu Lake were obtained. The major results of the study are listed in table1.

Results from table 1 showed that the sedimentation rate of Eastwulihu is much higher than that of Yuantouzhu and Sanshan in the late 20 years. It was found that the rapid increase of phosphorus fluxes in East wulihu lake is due to human activities especially agricultural irrigation and municipal drainage.

Table 1 The Sedimentation rates and sedimental fluxes in Taihu Lake

Sample site	Sedimentation rate(cm/a)	Sedimentation fluxes of P(mg/cm^2.a)
Yuantouzhu	0.05	0.021–0.025
Sanshan	0.10	0.044–0.054
East Wulihu(after 1980)	0.32	0.128–0.273
East Wulihu(before1976)	0.13	0.054–0.134

Many factors affect the release of phosphorus from sediment, such as temperature, pH, oxidation and reduction. The results were listed in table 2. It is found that release of phosphorus from sediment was obviously controlled by water pH value. Amount of phosphorus released from the sediment increased greatly at the low pH (<4) and high pH(>8)range, However, for 4.0< pH<8 range, the concentration of P released from sediment changed slightly. The effect of temperature on P released from sediment was obtained. Amount of P released increased with the increasing of temperature. There are more phosphorus released in Eastwulihu than Sanshan. Redox play an important role for phosphorus release from sediment. It is also found that the maximum value of phosphorus release under anaerobic condition is significantly higher than under aerobic condition [10].

Table2 The effect of environment condition on Phosphorus release from sediment

Environment condition	Release equation（$\mu g \cdot g^{-1}$）	Correlation coefficient（r）	Average release speed
pH			（$\mu g \cdot g^{-1} \cdot pH^{-1}$）
pH<4	Cp=93.6−28.8pH	0.9671	28.8
pH>8	Cp=−80.2+9.97pH	0.9470	9.97
4<pH<8	Cp=−1.46+0.53pH	0.9826	0.53
Temperature			（$\mu g \cdot g^{-1} \cdot ℃^{-1}$）
Sanshan	Cp=1.22+0.126t	0.9963	0.126
Wulihu	Cp=1.24+0.114t	0.9572	0.144
Redox			（$\mu g \cdot g^{-1} \cdot d^{-1}$）
Aerobic	$Cp=5.54e^{-1.91/d}$	0.9920	2.75
Anaerobic	$Cp=38.2e^{-1.85/d}$	0.9461	3.14

Cp：released amount of phosphorus（$\mu g \cdot g^{-1}$），t：water temperature（℃），d：day

A dynamic and static artificial system was employed to evaluate its effect on algae growth in sediment, Figure1 shows the result of the simulation research (dynamic and static) when the external sources are cut off. When the sediment coexists with algae, the growth rate of algae under aerobic condition is 7.74×10^3 Cell $\cdot ml^{-1} \cdot h^{-1}$ (static) and 2.04×10^4 Cell/$ml^{-1} \cdot h^{-1}$(dynamic)respectively, if the phosphorus is released first before culturing algae, the rate is only 1.35×10^3 Cell $\cdot ml^{-1} \cdot h^{-1}$. It is evidence that the exist of algae will destroy the phosphorus balance in sediment-water interface and accelerate the release of P in sediment. On the other hand, the release of P also accelerate the growth of algae. Whether in aerobic or anaerobic condition, the filtrate through 1.2 μm filter has the higher ability to accelerate algae growth than that through 0.45 μm filter, so we can draw the conclusion that the particle P is of bioavailibility [11].

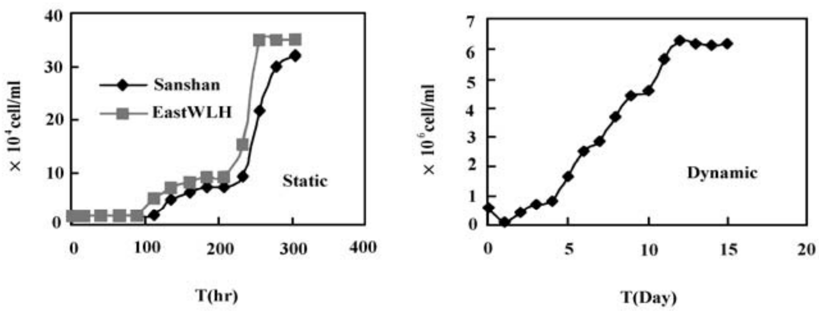

Fig. 1 The effect of sediment on the growth of algae

The changes of phosphorus species in water were determined after simulation experiment. The results were listed in table 3. Compared with the absence of algae, the concentration of total phosphorus in water increased while the soluble phosphorus decreased, so soluble phosphorus has priority uptaken by algae.

Table 3 Species of phosphorus after the sediment coexist with algae ($\mu g \cdot L^{-1}$)

Species of P	Sanshan		East Wulihu	
	algae	No algae	algae	No algae
Total P	80.5	33.5	117	71.7
Total reaction P	59.5	19.5	70.2	37.5
Total soluble P	10.0	29.9	25.0	66.3
Soluble & reaction P	2.85	4.38	7.33	23.4
Particle P	70.5	3.58	91.9	5.40

The phosphorus species of sediment were studied in simulation experiment, The results showed that P_{org} and P_{Al} were released prior to the others (see Fig. 2). There exists a significant correlation relationship between P_{org} or P_{Al} species and growth of algae. The correlation coefficient for P_{org} or P_{Al} is 0.9,273 and 0.9,874 respectively. Amount of P_{org} is about 20% of total phosphorus in sediment, so the bioavailability of P_{org} is unneglected[12]. Figure3 indicated that the growth rate of algae in East wulihu lake is higher than that in Sanshan in a stimulated natural system.

The concentration of phosphorus species in Taihu Lake was determined. The bioabailability of phosphorus species in lake water by algae was also investigated[14]. It was found that the soluble reaction phosphorus (SRP) was the first species to be uptaken by algae, total soluble phosphorus(TSP) was the second. The correlation equation between P species and algae growth was obtained. According to multiple regression analyses, simplified model between algae biomass(Y) and the phosphorus species is as follows:

$$Y=1.04\times 10^4 C_{PP}+4.97\times 10^3 C_{TSP} \qquad (r=0.9759,\ n=19),$$

Where: C_{PP}—the concentration of particular phosphorus;

C_{TSP}—the concentration of total soluble phosphorus.

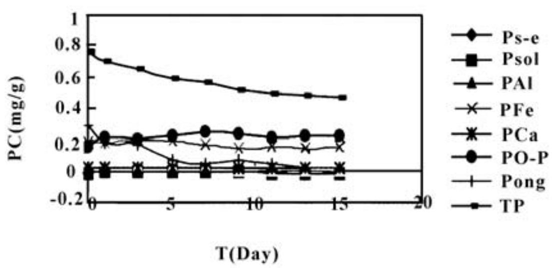

Fig. 2 The effect of algae on the species of phosphorus in sediment

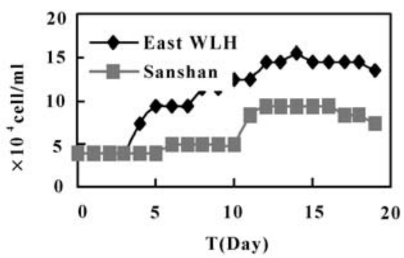

Fig.3 Growth curve of the algae in stimulated natural system

The effect of microorganism on the release of phosphorus, especially the possible transformation from phosphate and organic phosphorus to phosphine has arisen great interest among scientists. In the state of Colorado, USA. Lewis et al, found that the sedimental flux of phosphorus reached summit in mid-summer every year in two lakes, with products from reaction between phosphine and other compounds as the main components of the settlement. And phosphine was also found in the sediment of Hamberge harbor and wastewater treatment plant, in the urine of people and animal in Germany. Phosphine is one of trace gases widely existing in the atmosphere. Results showed that more than 400 million tons phosphine entered atmosphere every year, part of which is thought to come from the reductive reaction of the phosphorus compounds in sediment. It is an important complement to the theory about the cycle of phosphorus if it is testified by further study. It is also of great value to investigate the hypothesis that whether phosphine directly contribute to the death of aquatic creatures when the lake is in the state of eutrophication[14].

Conclusion can be drawn from above discussion that great attention should be paid to the release of nutrient from sediment when efforts are made to reduce the input from external source during control of eutrophication. Previous practice of cleaning the surface sediment which contains plenty of nutrient and toxicant matter is effective in controlling inner source pollution, which has been testified in many small lakes[15]. As it is impossible to clean all the surface sludge in so large area of Taihu Lake, efforts should be focused on the heavily polluted areas such as Wulihu, Meilianghu etc., where the content of TN, TP and TOC is about 0.18%, 0.12%, 2.15% respectively. It must be stressed that care must be paid to the cleanup so as to avoid water pollution caused by such action and new technology of high efficiency is urgently needed for the practical use.

2.3 Ecosystem remediation

Hydrophyte can decontaminate water and reduce the biomass of algae in lake ecosystem because it possesses such function as resisting wind and wave, promoting sedimentation , stabilizing sludge , absorbing and uptaking contaminants etc. During the process of eutrophication in Taihu Lake, the destruction of hydrophyte accelerated the deterioration of whole ecosystem. In the process of controlling entrophication and deterioration of water quality, efforts are focused on the growth of plant in coastal area and cutting off input of pollution from external source, which is key to the recovery of whole ecosystem, improvement of self-cleaning ability step by step and inhibiting the growth of algae[16].

2.4 Study on algae bloom occurring mechanism, prediction model and direct control technology

Algae bloom, occurring more frequently owing to Eutrophication, severely affects water supply and lake ecosystem. It’s preferable for us to take effective methods to avoid algae bloom in the control of lake entrophication .It is very difficult to control algae bloom effectively in short time by reducing nutrient from external and inner source into Taihu Lake, which is of heavy eutrophication at present. Consequently, it is impossible to recover its ecosystem in the not far future. Prediction control model has been established based on the relationship between algae bloom and environment factors as nutrition level, weather and water condition, and biological environment [17], which is regarded to relate closely to algae bloom. Even though great success has been made on the prediction of algae bloom[18], it is still long way to make precise prediction of algae bloom due to lake of knowledge on its mechanism. Future research should be focused on the following fields: investigation of mechanism about algae bloom in Taihu Lake, establishing prediction and control model of multi-factors , exploring direct control technology for algae bloom which is friendly to ecosystem . Thus, algae bloom could be inhibited by controlling potential factors when nutrition control and ecosystem recovery is not effective in short time, which save time to control entriphication and lessen the loss due to algae bloom, facilitate the ultimate solution to algae bloom.

2.5 Strengthening management on Taihu Lake

As effective management is essential in the process of aquatic eutrophication control, experience achieved in the developed countries should be learned to perfect Taihu Lake managing system gradually and to set up special funds to encourage systematic research on Taihu Lake protection under permission of present economy. It is suggested to establish automatic monitoring system in Taihu Lake to monitor water quality continually. Stipulations should be made and carried out effectively with the help of any possible means including administration, law and economy. Last but not least, in order to achieve the object of recovery of its ecosystem and to maintain the achievement, civilians should be encouraged to adopt the environmental friendly ways including living, cultivating, fertilizing, and land using etc.

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The Lakes Status in The South of Russian Far East and Problem of Their Pollution (On example of Khanka Lake)

Kachur Anatoly N.

Pacific institute of geography Far East branch of a Russian academy of sciences

Abstract Far East of Russia has many lakes and reservoirs. The lakes water contamination and their watershed is actual problem in all nature zones, but only at the south of region it resulted in eutrophication problem. A problem of a condition of an environment of basins of lakes of the south of Far East of Russia is shown on an example of basin of Khanka lake. The ecological problems of the basin are generated by as underestimation of peculiarities of natural conditions as imperfect forms of economic policy in agricultural-production sphere and in the raw materials mineral complex, also by irrational use of waters, absence of effective cleaning facilities at the industrial and municipal services spheres. The pollution of soils, natural waters, and then, correspondingly of agricultural products happens in result of use of so-called local mineral raw materials as fertilizers; application of broad set of chemical weeds- and pest-killers; unbalanced application of organic and mineral fertilizers; pollution by heavy metals and hydrocarbon combinations. The main problem in status of surface waters of the basin is lake eutrophication that determined by contents of bioorganic elements. For the decision of ecological problems of basin is offered new functional zoning of basin for transition nature using on sustainable development type.

Key-words Lake Pollution Eutrophication

Far East of Russia has many lakes and reservoirs. For example, only in the basin of Lena River more than 327 thousands of them are totaled /11/. Little bit less lake is in basins of the rivers of Amur, Kolyma and others.

The large part of lakes is in northern part of region. In southern part of Far East the amount of lakes is less, but here their significance for economy is huge.

The lakes water contamination and their watershed is actual problem in all nature zones, but only at the south of region it resulted in eutrophication problem. At the south of Khabarovskiy Kray and in practice almost totally on Primorskiy Kray the eutrophication of lake waters and water storage is the serious problem related to negligent consideration of natural processes in natural water management. The main problem in status of surface waters of the basin is their pollution by biogenic substances. Lake Eutrophication is determined by contents of biogenic elements /13/.

1 Present Status of Pollution of Lake

It is considered that reservoir eutrophication begins with contents of nitrogen −0.2–0.3 mg/dm^3 and phosphorus −0.01–0.02 mg/dm^3. In table 1 are ratio between trophic type of lakes and some other environment factors /1/.

Table 1 **Ratio between trophic type of lakes and some environment factors**

Trophic type	H ev. m.	Transparency m.
Oligotrophic	<u>18.2</u>	<u>9.5</u>
(maintain lakes)	12.0–22.1	6.0–25.0
Mesotrophic	<u>3.3</u>	<u>1,53</u>
	1.0–11.1	0.6–3.0
Eutrophic	<u>1.4</u>	<u>1.01</u>
	0.2–4.1	0.3–2.2

Note*:* Above line is average value Under line is range of indicators

Cultivation of natural virgin soils and application of mineral fertilization is changing biological circulation of elements being characteristic for the bio-chemical zone and resulted in increase of element migration according to the soil profile with lowering water stream. The most significant is nitrogen migration in nitrate form.

Addition of phosphorus fertilization is not forcing significantly to phosphorus migration down along the soil profile due to the soil having great sorption capability for phosphorus. Its high coefficient of biological absorption assists to retention of phosphorus in upper part of soil profile. Phosphorus discharge from cultivated territory occurs jointly with surface effluents.

Ratio of phosphorus quantity migrating in solid or liquid phases of surface effluents depends on conditions of effluents origin, namely growth of percentage contents of phosphorus in solid phase bound with granule-metric contents of effluents to cause increase phosphorus concentration in liquid phase.

Addition of mineral fertilization little forcing to total phosphorus storage is magnifying the storage of its water-soluble forms in liquid phase of surface effluents. This phosphorus is mainly in mineral form.

In soils under natural vegetation the concentration of phosphorus mineral form is very scarce in its water-soluble forms composition and in the soils of hydromorphic type is totally absent.

2 Present Status of Pollution of Khanka Lake

The Khanka Lake is a boundary lake between China and Russia. The Khanka Lake is the largest freshwater lake in Eastern Asia /8/. The Khanka Lake basin belongs to a number of territories in the southern Far East with the most considerable ecological load /5, 9/.

In Khanka Lake the main form of binded combined nitrogen is NH_3–N, the content of NO_3–N is also considerable. Nitrites are basically in considerable concentrations /3,6,9/. Average annual concentrations and intervals of the obtained concentrations of $NH_{3,}$ NO_3 and mineral phosphorus are given in Table 2.

Table 2 Average Annual Concentrations and Intervals of NH_4, NO_3 and Mineral Phosphorus Concentrations

Year	Concentrations, mg/L					
	NO_3		NH_4		Mineral phosphorus	
	Interval	Average annual	Interval	Average annual	Interval	Average annual
1985	0.04-0.39	0.15	0.05-1.01	0.23	0.000-0.038	0.012
1986	0.00-0.26	0.03	0.00-3.44	2.43	0.000-0.091	0.025
1987	0.00-0.26	0.03	0.00-4.44	2.43	0.000-0.091	0.025
1988	0.01-0.49	0.03	0.78-3.00	1.54	0.017-0.059	0.031
1989	0.00-0.65	0.06	0.12-4.92	1.28	0.000-0.190	0.049
1990	0.00-0.43	0.06	0.00-0.92	0.20	0.000-0.175	0.040
1991	0.00-0.60	0.07	0.00-38.20	1.34	0.000-0.154	0.015
1992	0.00-0.81	0.07	0.00-4.31	0.10	0.000-0.088	0.039
1993	0.01-0.40	0.04	0.00-0.98	0.14	0.000-0.052	0.009
1994	0.00-0.18	0.04	0.00-1.21	0.32	0.000-0.073	0.013
1995	0.01-0.32	0.06	0.00-0.49	0.10	0.000-0.063	0.009
1996	0.00-0.10	0.04	0.00-0.68	0.22	0.000-0.061	0.022
1997	0.00-0.22	0.03	0.00-0.38	0.04	0.000-0.043	0.024
1998	0.01-0.44	0.08	0.00-0.81	0.05	0.000-0.146	0.035

Analysis of Table 1 shows that their concentrations decreased in the 1990-es years. But they are still above the eutrophication criterion. Portion of NH_3–N in the budget of the combined nitrogen is increasing in transition from olygotrophic to meso- and eutrophic lakes.

Table 3 Ratio of Average Annual Concentratrations of NH_4 and NO_3 Nitrogen

Year	Average annual concentrations of nitrogen mg/L		Ratio of concentrations
	NH_4	NO_3	
1985	0.23	0.15	1.5
1986	2.43	0.03	81.0
1987	2.43	0.03	81.0
1988	1.54	0.03	51.0
1989	1.28	0.06	21.3
1990	0.20	0.06	3.3
1991	1.34	0.07	19.1
1992	0.10	0.07	1.4
1993	0.14	0.04	3.5
1994	0.32	0.04	8.0
1995	0.10	0.06	1.4
1996	0.22	0.04	5.5
1997	0.04	0.03	1.3

Analysis of Table 2 shows that concentrations decreased in the 1990s. But they are still above the eutrophication criterion. Portion of NH_3–N in the total amount of the combined nitrogen is increasing in transition from oligotrophic to meso- and eutrophic lakes. A ratio of average annual concentrations of NH_3–N and NO_3–N given in Table 3 confirms a conclusion that the abatement of anthropogenic load and rising of the lake level have slowed down the pace of its eutrophication.

Among heavy metals the highest concentrations of Cu are marked out (Table 4), which contents are stipulated strictly in fishery-economic reservoirs in the Russian Federation (maximum allowable concentration (MAC) is 1 μg/L).

The maximum concentrations of copper sometimes exceeding the high level of pollution (30 MAC) and the extremely high level (100 MAC) were marked out in the lake at Kamen-Rybolov settlement. In the southern part of the lake the increased contents of copper were found; their source is not clear still. It is necessary to mark out that totally the contents of dissolved copper in Khanka Lake and rivers of its basin are close to the regional magnitudes. The same characteristic is for contents of other heavy metals as well. In the 60–70 intensive rice cultivation began in the zone immediate to the lake. Pesticides become the main pollutants in the basin.

By the middle of the 1980 rice irrigation systems surrounded the lake by 160-km zone (since the lake coastline is 308 km on the Russian territory).

The high anthropogenic discharge has coincided with a phase of natural decrease of the lake water level that from the end of the 1980 to the beginning of the 1990 had led to the extremely high level of various pollutants concentrations in the waters.

Table 4 Average annual concentrations of Cu in waters of the khanka lake basin (μg/L)

Years	The rivers, running into lake				Khanka lake	The river, following from lake
	Spassovka	Ilistaya	Melgunovka	Komissarovka		Sungach
1988	12	8	7	6	7	3
1989	12	25	10	12	7	10
1990	10	9	7	5	5	—
1991	8	5	4	8	10	5
1992	3	2	2	10	6	16
1993	12	7	5	6	6	5
1994	8	6	6	8	11	5
1995	8	4	10	4	5	—
1996	5	5	14	5	6	—
1997	3	7	3	2	3	6

The maximum concentrations of agrochemical are marked out in 1987–1989 years. The diminution of pesticides contents in the lake water in the 1990 is consequence of redacting volumes of their application, reduction of sowing areas occupied by rice and natural rise of the lake level.

The total quality of the Khanka Lake water according to hydrochemical parameters during 1985–1992 was evaluated as “very dirty”, “dirty” or “polluted” /9/.

By 1996–1997 years the water of the lake according by its quality class became “moderately polluted” in the places of observations - Astrakhanka and Sivakovka and “clean” in Troitskoe and Novoselskoe settlements.

Distribution of polluting substances in the lake is non-uniform. If growth of petroleum products contents is marked out in the northern part of the aquatic area, pesticides and phenols - in the southern. The area of maximum pollution by biogenic substances is, first of all, at the Spassovka River mouth.

The index of saprobility is a criterion for evaluation of water quality by hydrobiological parameters. According to it the lake water in all inspected water areas is referred to the "temperately polluted" class.

Melgunovka and Ilistaya rivers are also considered as "temperately polluted", and the ecosystem of the Spassovka river lower then Spassk-Dalniy city is constantly in condition of oppression and regression.

Taking into account various components in evaluation of environment quality in correspondence with ecological-sanitarium classification, it is possible to say that at present Khanka Lake is "moderately polluted", and only in its separate parts the pollution is noticeably increased.

There is preliminary information on composition and seasonal dynamics of zooplankton, caddis flies fauna, aqua hemipterous and sarcophagous, lepidopterous and beetles.

According to the references (Kurentsov, 1970; Belyayev etc., 1989; Korshunov, Gorbunov, 1995; Chichvarkhin, 1997; Dubatolov et al., 1998) and data received by Yu. N.Gluschenko there are 188 species of *Lepidoterous* or daytime butterflies (*Lepidoptera*, *Diurna*) 6 families, 94 genera in the Khanka Lake basin /4, 10, 12, 14/.

The representation of the families is the following: *Nymphaliadae*- 62; *Lycaenidae*- 54; *Satyridae*- 20; *Pieridae*- 16; *Papilionidae* – 8 /10/. The dynamics of dominant species of *Cyanophyta* conducing to water "bloom" (*Microcystis, Aphanizomenon, Anabaena*) is very interesting in the lake. "Blooming" zones over 20 km in width totally cover the lake surface. The algal layer reaches 1,5-2 m thickness. Mass development of diatoms that provoke under-ice Melosira's "blooming" is marked in spring and in wintertime. The systematic list of algae in Khanka Lake included 80 species and forms of algae including diatoms: *Chrysophyta* - 3, *Euglenophyta* - 4, *Xanthophyta* - 2, *Chlorophyta* - 48, *Cyanophyta* – 23 /14/.

The phytoplankton is characterized by constant presence of diatoms which are the most abundant in autumn. In summer the most abundant are *Cyanophyta* of genera *Microcystis, Gloeocapsa, Aphanothece* and especially *Anabaena*, which vegetation continues till late autumn. "Blooming" of the lake due to mass development of *Cyanophyta* and colonial filamentous algae coupling with diatoms was noted in Trostnikovoe Lake (bay in Khanka Lake).

According to the last data 180 species and intra-species taxons of algae: *Cyanophyta* - 26, *Euglenophyta* - 9, *Dinophyta* - 1, *Cryptophyta* - 4, *Chrysophyta* - 12, *Bacillariophyta* - 64, *Xanlhophyta* - 1, *Chlorophyta* - 62 were found in Khanka Lake basin /14/.

In winter and spring diatoms present the main biomass of phytoplankton and its species variety. In summer and autumn the number of *Chlorophyta* species increases and their biomass becomes comparable with diatoms biomass. In July and October the phytoplankton biomass equally consisted of the following species: *Snowella rosea (Snow) Elenk*, species of diatoms genera *Synechocystis, Gloeocapsa, Synechococcus, Merismopedia of Cyanophyta; Stephanodiscus, Cyclotella, Nitzschia, Navicula, Aulacoseira, Schroederia setigera Lemm., Ulothrix tenerrima Kutz.*, species of Chlorophyta and *Chrysophyta* from *Ankistrodesmus, Monoraphidium, Scenedesmus Dinobryon divergens lmh* and *Mallomonas tonsurata Teil* genera.

3 Design Programm a Sustanable Development

As it shown by above-mentioned data the lake Khanka contamination in recent years is relatively diminished. It is related to sharp drop of economical activity first of all in the watershed. To prevent alteration of ecological situation towards deterioration when restoration of economics and its further development take place we offered the system of nature management, which is based on the concept of sustainable development.

The primary objectives system of nature management is:

- Evelop complementary land use policies and an equitable exchange of data among Russia and China of nature management concerning land-related issues in the Khanka Lake watershed;
- Esign an economic development program that is truly sustainable, inextricably linking economic development and environmental protection;
- Provide an improved quality of life for people living within and adjacent to the watershed;
- Preserve, and restore the biological diversity and natural ecological processes within the watershed;
- Evaluate the existing and probable results of present land use policies in relation to those of ecologically sustainable development policies;
- Develop performance standards for existing and future land use that will minimize environmental damage and preserve long-term land productivity /7, 15/.

For this purpose we elaborated the first variant of functional zoning of watershed /15/.

Of the first priority permissible and prohibited types of economical activity are estimated for each separated zone.

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Present Status and Conservation Measures of Water Environment in Japan

Ryuichi SUDO [1] and Kaiqin XU [2]

1) Department of Civil Engineering, Tohoku Institute of Technology, Sendai 980-0481, Japan

2) National Institute for Environmental Studies, Tsukuba 305-0032, Japan

Abstract Water pollution problems in Japan have shown an overall improvement and grown out of what was so serious as before, but there still exist areas which further improvements must be made. To conserve the sound water environment, it is important to raise the people's environmental consciousness, to strengthen the environmental education about the deterioration of the global environment. To raise the people's awareness about the need to overcome the crisis that humankind faces regarding "sustainability", and to ensure development of human society is also important. The present status and future prospects of water pollution and water environment are described in this paper. Water conservation measures for enclosed water bodies such as lakes and sea areas, countermeasures for domestic wastewater, and important targets on future environmental studies are also discussed.

Key-words Water quality Eutrophication Domestic wastewater Water environment Nitrogen Phosphorus

1 Introduction

Water pollution problem has become a worldwide problem. It is important to consider water environment conservation in global scale to restore our water environment as more as possible for our next generation. During the period of rapid economic expansion after World War Two, the environmental contamination and nature destruction became major social problems in Japan. In retrospect, these problems arose from the insufficient consideration on the environment. In an effort to resolve these problems, the Basic Law for Environmental Pollution Control and the Law for the Conservation of the Natural Environment were enacted, and pollution control and nature conservation polices were implemented based upon these laws. These policies, combined with efforts of both citizens and local governments, corporate investment in pollution prevention and technological developments showed remarkable results by the mid-1980s. Likewise, an effort to conserve the natural environment revealed considerable results.

Since then, Japan has continued steady economic growth. During these years of economic growth, mass-production, mass-consumption and mass-disposal have become an even more integral part of both Japan's socioeconomic activities and its lifestyle. Further concentration of population and socioeconomic activities in urban areas were experienced. In these circumstances, sufficient improvement have not been observed in urban and domestic-type pollution such as urban air pollution by nitrogen oxides, water pollution by domestic wastewater. The quality of underground water and sources of drinking water has deteriorated. Although water pollution problems in Japan have shown an overall improvement and grown out of what was so serious as before, there still exist areas which further improvements must be made.

For these reasons, Japanese government including the Environment Agency, has made great efforts in the research and control projects concerning the household wastewater treatment, not only for the removal of BOD, COD, but also for nitrogen and phosphorus removal. A series of laws and regulations have been established. The regulation concerning the prohibition of the penetration of harmful substance through soil, nitrogen and phosphorus effluent standard for coastal area, and Law concerning the Conservation of Water Resources were enacted in September 1989, October 1992, and February 1993, respectively. Especially, in November 1993, the Basic Environment Law was enacted, three basic ideals are taken up. They are the enjoyment and succession of environmental blessings, the building of a sustainable society and the promotion of conservation of the global environment through international coordination. In accordance with the Basic Environmental Law, the Basic Environment Plan was established in December 1994, as a long-term comprehensive national plan for environmental conservation. Sound material cycle, harmonious coexistence, participation, and international activities were included as four basic concepts in this plan.

In this paper, the present status and prospects, and conservation measures of water environment, and water environment research targets were represented [1)-4)].

2 Present Status of Water Environment

The outline of water pollution based on the findings of surveys on the water quality of public waters across the nation in fiscal year 1998 can be shown as follows.

Regarding health items under environmental quality standards for water, a total of 15 items was added under the notification of March 1993, including trichloroethylene, tetrachloroethylene and seven other organic chlorine compounds and Simazine and three other pesticides. The total of items was set at 27 by excluding organic phosphorus from the environmental quality standards. From the standpoint of preventing water pollution, it has been decided to designate chloroform, toluene and other items as those requiring surveillance, continuously monitoring water to cope with future pollution in a flexible manner (Table 1). The rate of sample which exceed environmental quality standards was exceedingly low. In regard to health related pollutants, such as cadmium, the percentage of in excess of environmental quality standards was 0.01%(Fig. 1) . For trichloroethylene and tetrachloroethylene, the percentage of samples in excess of target value was 0.3% and 0.5%, respectively.

Tabke 1 Health items in environmental quality standards for water

(a) Items in environmental quality standards for water		(b) Items requiring surveillance and values under guidance	
Item	Standard value	Item	Value under guidance
Cadmium	0.01	Chloroform	0.06
Total cyanogen	Not to be detected	Trans-1,2-dichloroethylene	0.04
Lead	0.01	1,2-dichloropropane	0.06
Sexivalent chrome	0.05	Dichlorobenzene	0.3
Arsenic	0.01	Isoxathlon	0.008
Total mercury	0.0005	Diazinon	0.005
Alkyl mercury	Not to be detected	Fenitrothion	0.003
PCB	Not to be detected	Isoprothiolane	0.04
Trichloroethylene	0.03	Chlorothalonil	0.04
Tetrachloroethylene	0.01	Propyzamide	0.008
Carbon tetrachloride	0.002	Dichlorvos	0.01
Dichloromethane	0.02	Fenobucarb	0.02
1,2-dichloroethane	0.004	Chloronitrophen	0.005
1,1,1-trichloroethane	1	Iprobenfos	0.008
1,1,2-trichloroethane	0.006	EPN	0.006
1,1-dichloroethylene	0.02	Toluene	0.6
cis-1,2-dichloroethylene	0.04	Xylene	0.4
1,3-dichloropropane(D-D)	0.002	Diethylhexyl phthalate	0.06
Thiram	0.006	Nickel	0.01
Simazine(CAT)	0.003	Antimony	0.002
Tiobencarb	0.02	Molybudenum	0.07
Benzene	0.01		
Selenium	0.01		
*Boron	0.2		
*Fluorine	0.8		
*Nitrate nitrogen and nitrite nitrogen	10		

* added items in Feb. 1999

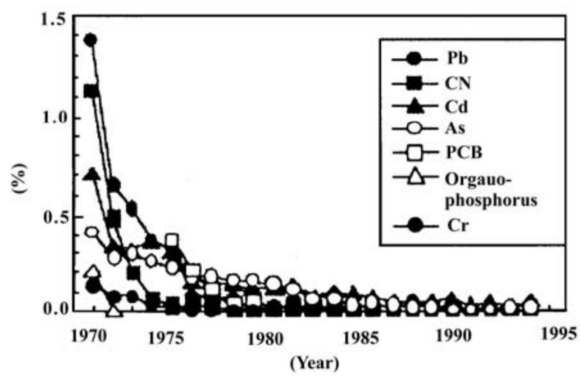

Fig. 1 Trends in item-specific rate of noncompliance in relation to health items under environmental quality standards for water

(However, the rate noncompliance for alkyl mercury has been 0% since fiscal 1971.)Source: Environmental Agency

As regards the water quality associated with conservation of the human living environment, the projection made on the water quality of waters for public use in fiscal year 1999 indicated that the rate of achieving environmental quality standards stood at only 75.0%, suggesting that about one-fourth of all water bodies did not satisfy environmental quality standards (Fig. 2). By type of water body, rivers accounted for 81.0%, lakes and reservoirs 40.9% and sea regions 73.6%, and the achievement rate was low particularly for enclosed water areas such as lakes and reservoirs, bays, inland seas and medium and small rivers in cities. The rate for total nitrogen and phosphorus was 31.3% only. A check of long-term trends indicates that the controls specified in the Water Pollution

Prevention Law, and those added to them by prefectures, have made it possible to gradually improve the achievement rate for rivers though it stood at about 50% in or around 1975. The achievement rate for sea regions has stayed in the neighborhood of 80% in years other than 1983 and 1990, whereas the achievement rate for lakes and reservoirs remains low as in the past.

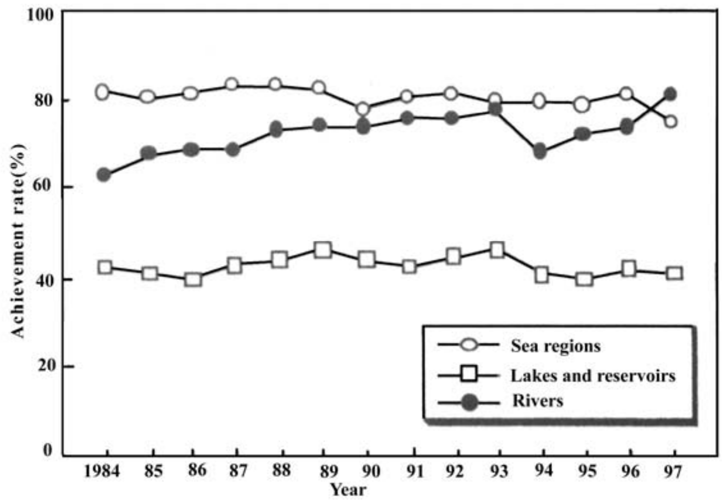

Fig. 2 Trends in achievement rate of environmental quality standards (BOD or COD)

Source: Environmental Agency of Japan

In Lakes and reservoirs, inland seas, bays and other closed waters, the exchange with outside water is so poor that pollutants tend to accumulate, making it difficult to improve the water quality. The ongoing eutrophication of lakes and reservoirs gives rise to such issues as tap water with offensive odor, impacts on fishery and a drop in transparency, making improvements in the water quality an urgent task. For Lakes Biwa, Kasumigaura, Suwa and six other lakes, for which a lake water quality conservation program is formulated under the Special Measures Law for Conservation of the Lake and Reservoir Water Quality, special measures are in force according to the program, in addition to the controls specified in the Water Pollution Prevention Law. However, environmental quality standards have still to be improved.

COD-associated areawide total pollutant load controls are exercised for the Bay of Tokyo, the Bay of Ise and the Seto Inland Sea under the Water Pollution Prevention Law and the Special Measures Law for the Environmental Conservation of the Seto Inland Sea. A check of the achievement rate of environmental quality standards (COD) for the three sea regions shows that the ratio is moving at lower rates in the Bay of Tokyo that in all sea regions and that it remains at a low rate for the Bay of Ise, though there have been some improvements (Fig. 3). For the Seto Inland Sea, the rate remains virtually at the same level but when it comes to the Bay of Osaka and other sea regions, it is changing slowly. Into those closed waters, nitrogen, phosphorus and other eutrophic salts, mingled with residential and industrial wastewater, flowing from major cities which form the hinterland creating eutrophication. For this reason, red and blue tides are generated, posing such threats as damage to fisheries, offensive odors, hazards to the use of sea-bathing resorts and beach pollution.

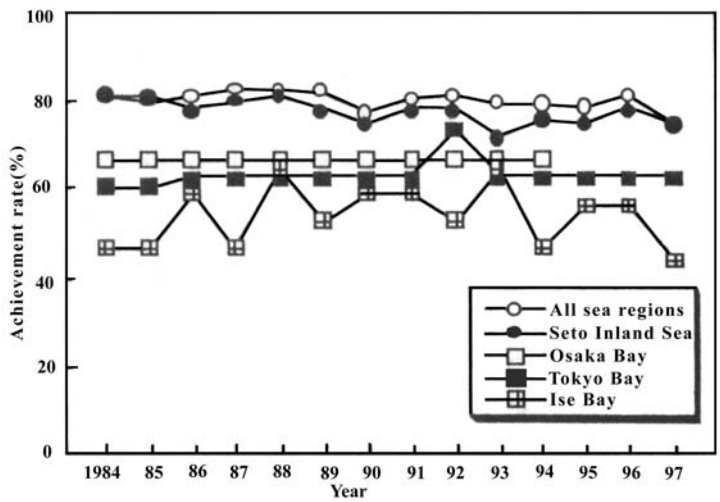

Fig. 3 Trends in achievement rate of environmental quality standards (COD) in 3 sca areas

Source: Environmental Agency of Japan

Groundwater has long been highly rated as a source of good quality water and constant in temperature. At present, it accounts for about 30% of water for use in urban areas. In the latter half of the 1975–1984 period. Groundwater pollution, such as by trichloroethylene came to the fore and widespread groundwater pollution was confirmed in fact-finding and other surveys. Given this situation, the Water Pollution Prevention Law was amended in June 1989 to control the underground penetration of water containing hazardous matter and for the central and local governments to carry out surveillance continuously.

3 Water Conservation Measures for Lakes and Sea Areas

Levels of organic pollution in lakes, marshes, inland seas, inner bays, rivers and streams in urban areas and other closed bodies of water have stabilized and, in some areas, have shown improvement. However, compared to other bodies of water, the improvements have been rather unsuccessful. To prevent water pollution, it is necessary to establish Environmental Quality Standards, to strengthen Effluent Controls, and to cope with domestic wastewater effluents.

For bays, inland seas, lakes and reservoirs and other closed waters particularly with significant pollution sources in the hinterland, the rates of achieving environmental quality standards are lower than that for other areas, because the pollutant loads are significant and pollutants tend to accumulate. In addition, the inflow of nitrogen, phosphorus and other chemicals leads to the progress of so-called eutrophication. The generation of red tides are frequently detected in the areas such as Tokyo Bay, Ise Bay , and Osaka Bay in the Seto Inland Sea . There were 42 cases in Tokyo Bay, 73 cases in Ise Bay and 107 cases in the Seto Inland Sea, and in Tokyo Bay and other bays, the generation of blue tides is also observed. There are now a few lakes and reservoirs where the generation of blue-bloom and freshwater red tides are detected. Given this situation, there is the need to further strengthen measures for the conservation of the water quality of closed waters.

The reason for the pollution of bays, inland seas, lakes and reservoirs and so forth, is due to physical features unique to closed water bodies. Polluted matter tends to accumulate. It is also due to socioeconomic factors, such as the concentration of population and industry in littoral areas. Concerning rivers in cities and lakes and reservoirs in areas where urbanization is in progress, the development of sewage systems does not catch up with increases in population. Furthermore, there are problems about non-point water pollution where pollutants are washed out by rain and so forth from built-up broad urban areas, sites where land is under development, farmland, etc., and water pollution by the discharge of nutrients deposited and accumulated in the bottom.

With the Water Pollution Control Law revision of 1978, areawide total water pollutant load controls were institutionalized for overall reduction in the loads of pollutants flowing into waters. This system is enforced for Tokyo Bay, Ise Bay and the Seto Inland Sea with COD taken up as a designated item. As concrete measures, household effluent measures, such as the promotion of the development of sewage systems and the development of community plants, effluent facilities for agricultural hamlets, combined treatment and combined gray and night soil treatment facilities and so forth, industrial wastewater measures, including the strengthening of areawide total pollutant load control standards, such as at factories, and various measures are being implemented in a comprehensive manner.

The Special Measures Law for the Conservation of Lake and Reservoir Water was enacted in 1984 and put into force in March 1985, and programs for the conservation of lake and reservoir water are formulated to promote measures. 10 Lakes—Biwa, Kasumigaura, Inbanuma, Teganuma, Kojima, Suwa, Kamafusa dam, Nakaumi, Shinji, Nojiri have been designated. For former five lakes, controls were also strengthened in October 1991 to implement measures for reduction in the discharge of nitrogen and phosphorus, and the second Lake and Reservoir Water Conservation program was formulated in March 1992. Now the third-stage water conservation plan in lakes and reservoirs that covers reduction of nitrogen and phosphorus has been adopted, and the regulations of nitrogen and phosphorus have been enhanced. Figure 4 indicates the environmental measures expecting to be established for lakes and sea areas in Japan.

Eutrophication, like the natural process of aging of lakes, in the broadest sense is the elevation in the supply of plant nutrients to natural waters as a consequence of human activities in the catchment areas and the resulting enhanced growth of algae and higher aquatic plants (primary production). In attempts to cope with eutrophication, which is a grave issue for lakes and reservoirs, the following measures are under way:

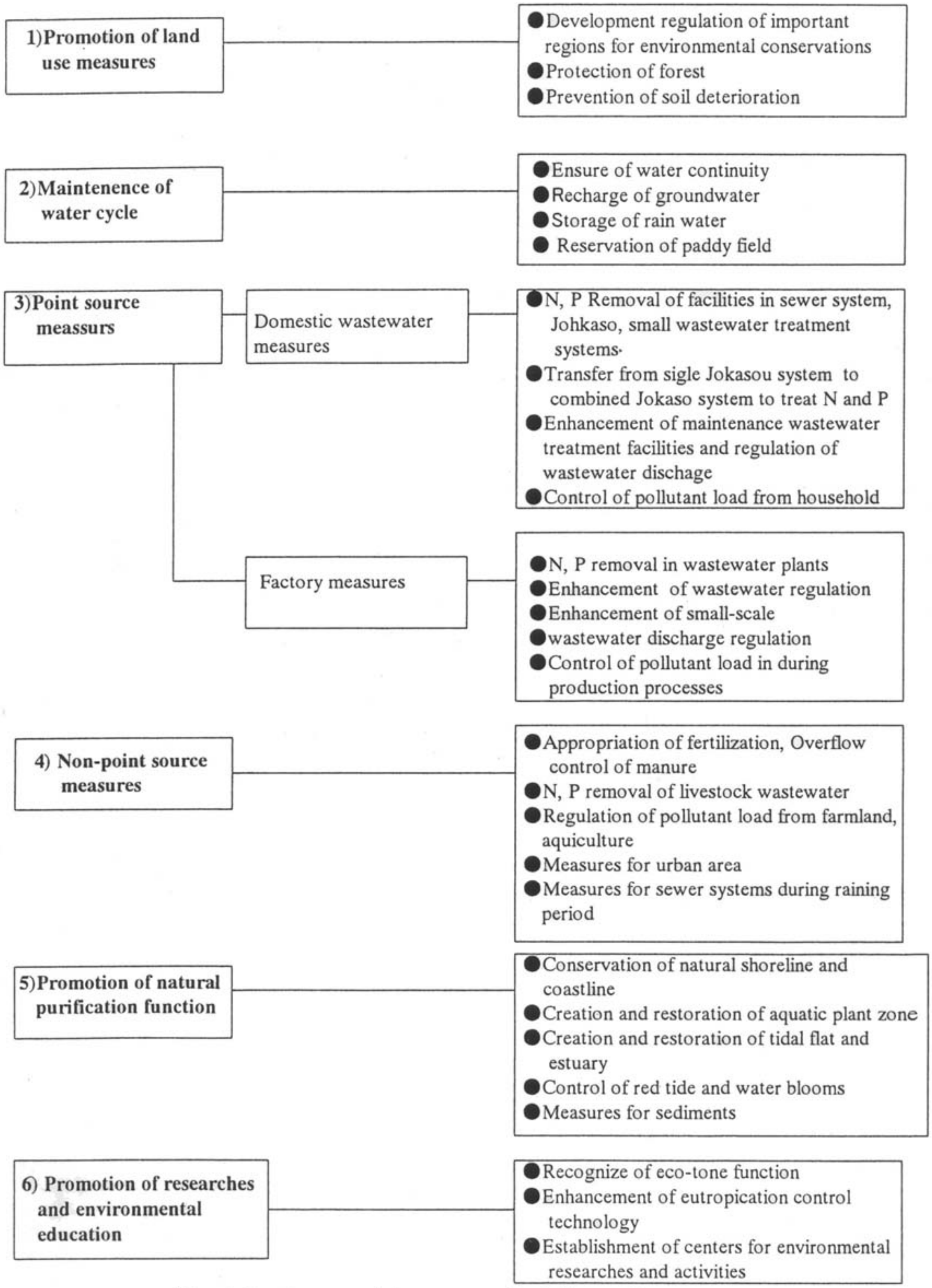

Fig. 4 Environmental measures for lakes and sea areas

In relation to lakes and reservoirs, notice was served on the environmental quality standards associated with nitrogen and phosphorus in 1982. Standards for nitrogen and phosphorus levels in effluent were established in 1985. Regulations are in place to enforce compliance with these standards at 1,200 lakes and reservoirs with respect to effluent containing phosphorus, and 201 of those lakes and reservoirs with respect to effluent containing nitrogen. The effluent standards for nitrogen and phosphorus in lakes and reservoirs are determined as less than 120 mg N /L and 16 mg P /L, respectively, which seems to be high. However, for some specific lakes which are enclosed and in danger of eutrophication, there are more strict effluent standards, for instance, the standards of nitrogen and phosphorus in Lake Kasumigaura are 8–10 mg N /L and 0.5–1.0 mg P /L. These standards were also applied to the closed sea region where its area is larger than 5 km^2 and its closed index is larger or equal to 1.

Table 2 Standards related to the living environment in Sea areasconservation (Nitrogen and Phosphorus)

Category	Total nitrogen (mg/L)	Total phosphorus (mg/L)
A	0.2	0.02
B	0.3	0.03
C	0.6	0.05
D	1	0.09

Purpose of water use
A : conservation of natural environment and uses listed in B-D
B : fishery class 1 ; bathing and uses listed in C-D
C : fishery class 2 ; use listed in C and D
D : fishery class 3 ; industrial water and conservation of environment for benthos

Closed index was defined as follows:

$$\text{Closed index} = (\quad S \quad D_1) \quad (W \quad D_2)$$

Where, *S*—area;

W—width of the closed bay mouth;

D_1—depth of the deepest point;

D_2—depth of the closed bay mouth.

Classifications are designated by the State and Prefectural governments, and up to 1994, 88 waters including Lake Biwa etc. had been designated. Similar Environmental quality standards associated with nitrogen and phosphorus for ocean areas have also been enacted in August 1993 (Table 2).

Controls on wastewater have been under way on nitrogen and phosphorus since July 1985. Pollutant load controls exist for nitrogen and phosphorus at Lake Biwa and six other designated lakes and reservoirs. As regards the Seto inland Sea, guidance is being provided on reductions in the discharge of phosphorus and its compounds in accordance with the Special Measures Law for Conservation of Seto Inland Sea Environment.

4 Measures for Domestic Wastewater

As already mentioned, the compliance ratios of BOD, COD for rivers, lakes and coastal waters were 73.6%, 42.0% and 81.1%, respectively, which still remains in low levels. Especially in urban rivers, lakes, inland sea and bays, the water bodies extremely eutrophicate because of the direct discharging of gray water, which represents a substantial portion of the total household effluents, and the wastewater from the small scale factories. They are almost 70 % of the total pollutants in public water areas. Furthermore, removal of nitrogen and phosphorus in effluent from domestic and industrial wastewater treatment facilities is most important to control the eutrophication.

Figure 5 shows the distribution of the pollutant load for each wastewater in typical polluted areas (Teganuma, Inbanuma, and Tokyo Bay). It can be seen that more than 60% of wastewater are from domestic wastewater, and most of the domestic wastewater comes from gray water. It suggests that if the control of gray water is delayed, the water environment conservation can not be reached.

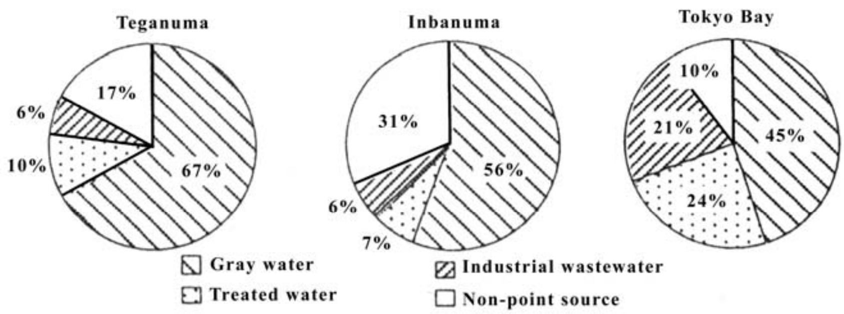

Fig. 5 Distribution of COD loading for type of wastewater in Lake Teganuma, Lake Inbanuma and Tokyo Bay

The main sources of gray water (household discharge excluding toilet) are from kitchens, baths, and washing. The proportions of gray water produced by various activities are : Cooking 27%, Laundry 30%, Bathing 25%, Lavatory sinks 8%, and others including house cleaning 10%. Both the quality and the quantity of gray water discharged from each family naturally varied according to the differences of life style, family composition, occupation, seasons of the year, weather, day of the week, and other factors. Kitchen is responsible to approximately 70% of the total pollutant load in gray water. Effective reduction of pollutants can, therefore, be achieved by the adequate control of the kitchen drainage. Measures to be taken at the kitchen are:

（1）to quip sinks wit fine mesh strainers that collect cooking wastes and leftovers;

（2）to cook appropriate amount of food to reduce cooking wastes and leftovers which should be disposed as garbage or buried in the ground;

（3）to wipe used dishes and cooking utensils with paper before washing;

（4）not to cast used oil into sinks;

（5）to avoid excessive use of soap and detergent.

Table 3 Pollutant loads from leftovers and cooking drainage

Item	BOD (mg/L)	T-N (mg/L)	T-P (mg/L)
Washed water for rice (4 person)	2,400	29	7.8
first washed water	11,100	111	32
Boiled water			
of Spaghetti	5,400	55	17
of Japanese noodle	1,030	22	6.3
Preparations of fish food	1,300	60	13
Chinese noodle soup	26,000	1,180	290
Miso (Japanese) soup	37,000		
Corn cream soup	126,000	1,300	210
Broth of boiled fish pastes and vegetables	95,000	4,200	970
Stock	1,730	210	82
Boiled water of pumpkin	87,000	5,200	830
Cooking of meat and potato	52,000		
Sauce of meat and tomato	150,000	2,400	370
Used cooking oil	1,400,000	1,400	30
Liquid detergent	200,000	3,200	10

Table 3 shows the BOD values in typical leftovers and cooking drainage common to Japanese kitchens. Housekeepers should remember the fact that 10 ml of disposed oil corresponds to 10 g of BOD, and try to achieve the effective control of the kitchen drainage. On the other hand, the average pollutant load per unit of gray water, night soil and domestic wastewater is shown in Table 4. It indicated that the pollutant load from gray water is almost twice of that from night soil, and amounts to 60%–70% of total load. It is important to reduce the effluent from kitchen drainage.

Table 4 Unit pollutant loadings and concentrations of gray water,night soil and domestic wastewater

Item	Cray water		Night soil		Domestic wastewater	
	Per capita loading(g/cap/d)	Conc.(mg/L)	Per capita loading(g/cap/d)	Conc.(mg/L)	Per capita loading(g/cap/d)	Conc.(mg/L)
BOD	27	180	13	260	40	200
COD	12	80	6	120	180	95
SS	13	87	22	440	35	175
T-N	1.3	9	6	120	7.3	37
T-P	0.3	2	0.5	10	0.8	4
MBAS	2.6	17	0	0	2.6	13
Volume	150/cap/d	50/cap/d	200 cap/d			

MBAS: Anionic surfactant

As described above, domestic wastewaters play a significant role in water pollution. Given this, there is the need to streamline sewage and domestic wastewater treatment facilities and enhance residents' consciousness. For this purpose, the following measures are taken:

（1）Environment Agency

①Formulation of the Guideline for Guidance on the Promotion of Measures to Cope with Household effluents (1988)

②Holding of the Water Environment Forum (annual)

③Partial amendment of the Water Pollution Control Law (June 1990)

i)Clarification of administrative work on measures to cope with household effluents and of the people's obligations

ii) Systematic promotion of measures to cope with household effluents

④In accordance with the amended law, priority areas are designated by prefectural governors. As of March 31, 1995, 132 districts and 369 municipal cities in 40 prefectures were designated.

（2）Ministry of Health and Welfare and Ministry of Construction

Designation of “Sewage System Promotion Day” (September 10 of each year)

（3）Environment Agency, Ministry of Health and Welfare and Ministry of Construction

Designation of “Johkaso's Day” (The day for on-site treatment facilities and combined gray and night soil treatment facilities) (October 1 of each year)

Development of sewage systems, development of surveillance and monitoring systems, investigations of uncontrolled items, purification measures are needed. To ensure sound water circulation in metropolitan areas, utilization of sewer refuse, vegetation, permeable pavement and the establishment of seeping measures for rainwater shall be promoted. Conservation shall be promoted in coastal waters, natural coastlines, tidal flats, seaweed beds and shallow water areas. Moreover, the development of artificial tidal flats and beaches, which also aid in water purification, shall be promoted. Universal methods for evaluating water quality, quantity, aquatic life and other aquatic environments shall be studied.

A survey by Sizuoka prefecture, Life environment Division, indicated that the above measures of source control could reduce the pollutants in the kitchen drainage to extents of 65% reduction of BOD, 65% of SS, 61% of T-P, and 63% of T-N. Another survey in Chiba prefecture tested filter paper for kitchen use and mesh filter for the effect to reduce pollutants. Kitchen filter paper could remove 50% of SS and 40% of oil and grease. Although these values should be regarded as the upper limits of reduction under an ideal control, it is considered possible to remove at least 30% of the pollutant in every household. Strong intervention to achieve this reduction should be promoted at the level of the social consciousness, since the comprehension and cooperation of the inhabitants are essential to the effective source control of the household discharge.

Stimulated by the regulations and Laws relating to environmental conservation, beside above measures, local governments have moved out to encourage the use of non-phosphate detergent and/soap, and as a result, use of phosphate detergent has been remarkably decreased.

Since the percentage of the population for whom sewer systems and other systems are applied is only 58% and 6.2%, respectively, (by the end of March 1999), the promotion of other systems including rural community sewage facility, gray water community plant, on-site wastewater treatment facilities, combined on-site wastewater treatment facilities and so forth are essential and important. Although it is expected that by 2000 the percentage of population applied sewer systems and other systems will be reached to 60% and 10%, respectively, 30% of the effluent of untreated domestic wastewater may still discharge to public waters. Meanwhile, it is difficult to transfer the single on-site treatment facilities (treated for black water only) to combined on-site treatment facilities in all regional areas in short periods. It is, therefore, important to systematically promote the measures to cope with domestic wastewater in more extended and wide areas and to strengthen the environmental consciousness of whole people's obligations. As for the treatment processes and systems, it is necessary to develop the systems suitable to regional characteristics, to follow the “dispersion” and “variation” principle as shown in Figure 6. “Dispersion” means to treat wastewater in separated area, “variation” means besides sewer, on-site treatment facilities, to use every effective system such as soil treatment, land treatment, lagoon, stream purification, wetland systems, biological wastewater treatment systems and so on. It is also needed to make effective use of ecotechnology and biotechnology or make reasonable combination of these treatment systems for the restoration of water environment. The technical development for the removal of nitrogen and phosphorus by using the combination of ecotechnology and biotechnology, and the efficiency promoting for the biological water and wastewater treatment must be also carried out to prevent eutrophication.

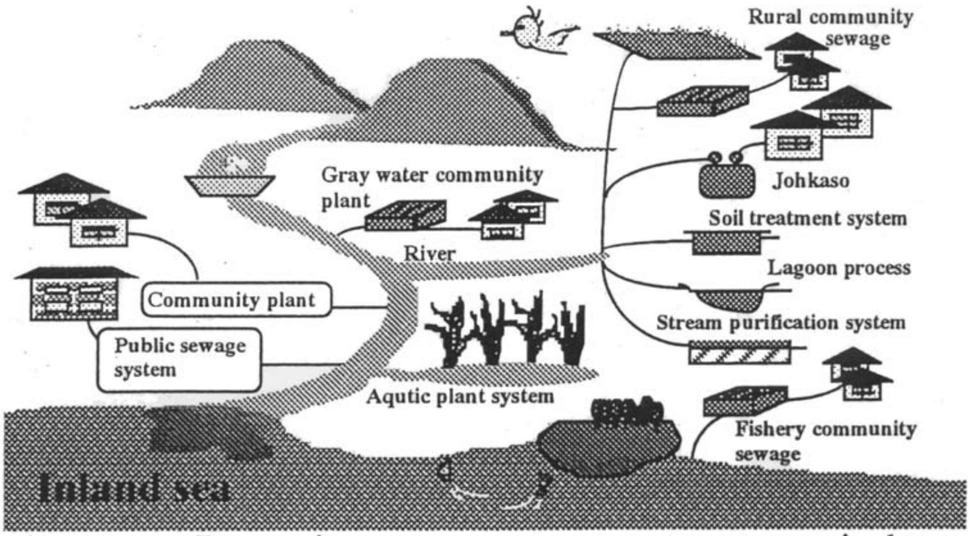

Fig. 6 Domestic wastewater treatment system suited to regional characteristics

5 Prospect of Water Environment

Rapid population growth and expansion of socioeconomic activities are threatening the Earth's environment, which supports the survival of humankind. Japanese society and its economy are beginning to mature after decades of tremendous growth. In the process, Japan consumed large amounts of natural resources and discharged great amounts of pollutants into the environment. Japan is expected to continue its present trend toward urbanization, but while doing so, it needs to control the burden inflicted on the environment from such activities. The dilemma does not stop with problems related to conserving the environment from mere discharge of regional pollution. There is still concern about ever expanding socioeconomic activities which harbor potentially detrimental effects for the environment. Like wise, it is feared that the sustainability of society itself is becoming increasingly uncertain.

It is easy to predict that if no further measures is taken, problems like toxic substance, organic pollution, eutrophication, trace chemical substance, harmful organisms, soil degradation, deforestation, acid rain and marine pollution will become grave issues in next century.

Table 5 Trends of water environment in future and countermeasures for conservation of the water quality

(1) Water environment

	1970	present	after 2010
Toxic substance	×	○	○
Organic pollution	×	△	△
Eutrophication	×	×	××
Trace chemical substance	△	×	××
Harmful organisms	△	△	×
Soil degradation	○	△	×
Deforestation	○	△	×
Acid rain	○	○	×
Marine pollution	○	△	△

○ : good ; △ : fair ; × : bad ; ×× : worse

(2) Measures for conservation of the water quality

	1970	present	after 2010
Countermeasures of			
Industrial wastewater	×	○	○
Eutrophication	×	×	△
Domestic wastewater	×	△	△
Small-scale wastewater	×	×	△
Non-point source	×	×	△
Soil preservation	×	×	△

○ : well done ; △ : not enough ; × : seldom done

Table 5 shows the image of water environment and conservation countermeasures in the past, present and after the year 2010. Environmental conservation countermeasures including industrial wastewater, eutrophication, domestic wastewater, small scale wastewater, non-point sources may be improved in some extend. However, it can be seen that toxic substance problem may be solved, while other problems including organic pollution, harmful organisms, acid rain, and marine pollution, especially, eutrophication, trace chemical substance, will become worse. The important subjects regarding water environment are considered as

（1）eutrophication of lakes and inland seas;

（2）organic pollution of middle or small rivers;

（3）contamination of underground waters;

（4）pollution of drinking water resources; and

（5）loss of the environmental amenities around water (waterside environment).

As the eutrophication problems progress, the extreme growth of poisonous picoplankton and the occurrence of water bloom, harmful bacteria, virus may even cause the crisis of water supply systems. These problems may result from the remarkable increment of N/P ratio, causing the abnormal growth of algae. It is undesirable to the conservation of lake ecosystems. The measures for non-point source pollution and small-scale wastewater may be expected to be enforced in earnest from year 2000. The control of micro pollutants such as organochlorine and agricultural pesticides is also an urgent problem.

Until now, environmental standards were discussed just relating to water quality only, from now on, it is necessary to deal with the items including waterside environment, characteristics of sediments, biology(vegetation and fauna), and natural scenery and so on.

Figure 7 shows the important targets addressed by Japan Environment Agency on future environmental studies and environmental technologies. Table 6 indicates the classification of the research contents. There are many problems relating to water environment such as toxic substances, conservation of ecosystems, wildlife problem, global environmental problems and so forth. Here we just focus on the water environment problems related to the conservation of living environment. It is indispensable to develop the techniques of low pollutant load system, low impact and easy removal and disposal system, environment restoration/renovation/establishment system as listed in Table 7. We should not remained the advanced treatment of wastewater and disposal of sludge, it is important to pay attention to the topics such as the creation of bio-top and biomanipulation in water areas.

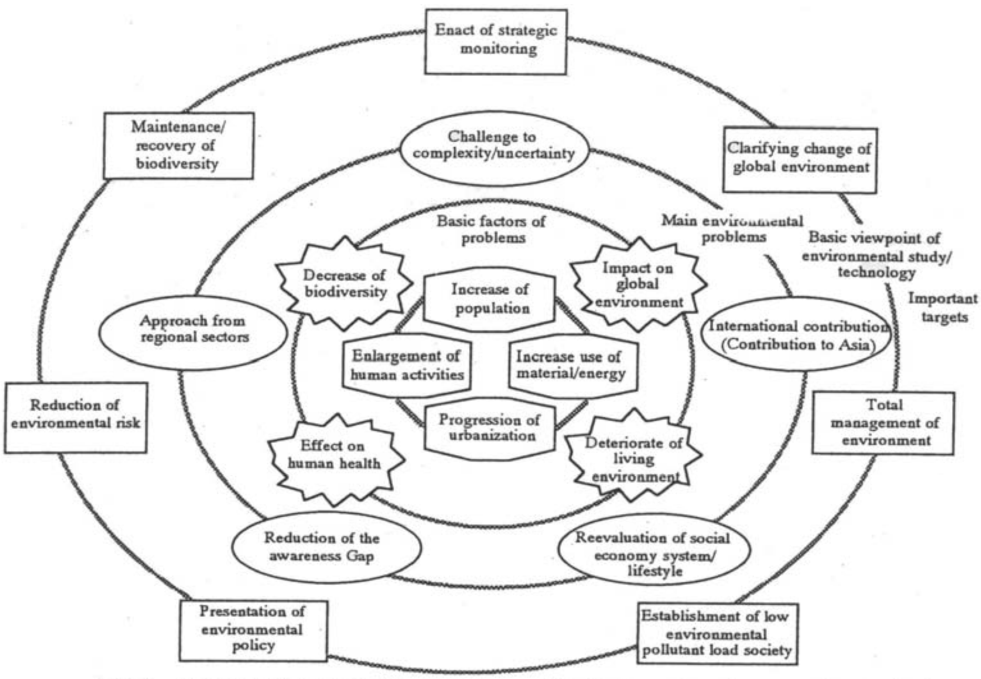

Fig. 7 Important targets on future environmental studies and environmental technologies

Until now we used to tackle the phenomenon on air pollution, offensive odor problems, it is necessary for us to make an approach to grasp the living environment as a total system. As for the promotion of the technique development, it is important to liaise with all the sectors including government administration, communities, universities, corporation companies and NGOs.

As for future research on water environment, it is necessary to emphasize the relationship among the water, soil and forest ecosystems. Namely, it is to change from the individual phenomenon to broad-based and comprehensive aspects. In case of research on the topics of lakes and reservoirs, it is essential to involve the whole basin management system to consider the forest-farmland-groundwater-river-lake and the atmosphere.

Table 6 Classification of the environmental research and environmental technology

1）General environment conservation
2）Conservation of global environment
3）Conservation of ecosystems
4）Conservation of wildlife diversity
5）Preventon of environmental impact of harmful substances etc.
6）Conservation of living environment and establish of delightful environment
7）Contact with nature

Japanese government including the Environment Agency, has made great efforts in the research and control projects concerning the household wastewater treatment, not only for the removal of BOD, COD, but also for nitrogen and phosphorus removal. And a series of laws and regulations have been established. Nevertheless, to achieve the targets, there still a long march for us to overcome. Thus, to maintain a sound water environment, sound material cycle, harmonious coexistence, participation and international cooperation, the policy emphasized in the Basic Environment Law, should be promoted.

Table 7 Classification by environmental research contents

1) Investigation research
(1) Monitoring, observation
(2) Phenomenon breakthrough
(3) Quantification, prediction
(4) Impact assessment
(5) Policy studies etc.
2) Technique development
(6) Low pollutant load system,
(7) Low impact and easy removal and disposal system
(8) Environment restoration/renovation/establishment system
3) Horizontal items
(9) Fundamental research, fundamental technology
(10) Power Structure system establishment etc.

Ecotechnology like wetland system, aquatic plant system, land treatment system, stream purification system, and some biological wastewater treatment systems should be established. The technical development for the removal of nitrogen and phosphorus by using the combination of ecotechnology and biotechnology should be carried out to prevent eutrophication problems[5)–9)].

6 Summary

Environmental pollution has emerged as man's activities strained the natural environment, thus damaging, in turn, his health and living environment. In Japan, industrial pollution of very serious proportions accompanying its high economic development became a grave social problem. However, this very serious industrial pollution has been mitigated thanks to continued efforts by the governmental and non-governmental quarters.

To conserve the sound water environment, it is important to raise the people's environmental consciousness, to strengthen the environmental education about the deterioration of the global environment. To raise the people's awareness about the need to overcome the crisis that humankind faces regarding “sustainability”, and to ensure development of human society is also important. The technical development for the removal of nitrogen and phosphorus by using the combination of ecotechnology and biotechnology should be carried out to prevent eutrophication.

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Internal Environmental Prevention and Cure Measures for Eutrophication of Lake Dianshan In Shanghai and The Analysis of Their Benefits

Wang Yun You Wenhui Gu Yongjie *Zhu Wei

Department of Environmental Sciences East China Normal University Shanghai, China

*Water Resource Protection in Drainage Area of Taihu Lake Agency Shanghai, China

Abstract This paper discussed three kinds of internal environmental prevention and cure measures for eutrophication of Lake Dianshan: dispatching washing water，planting aquatic and cultivating fish. This paper also analyzed those measures' environmental benefits and economic benefits. the conclusion of optimum seeking and sorting showed that：planting aquatic was the best measure to prevent eutrophication, the better one was fish cultivation and then the water dispatching.

Key-words Eutrophication Prevention Dispatching water Washing biological control Environmental benefits Economic benefits

According to the materials collected from China and foreign countries and research work in recent years about lake eutrophication prevention and cure, some effective measures had been chosen by screening. Besides external environmental prevention and cure measures，this paper mainly discussed internal environmental prevention and cure measures such as water dispatching and biological control.

1 Dispatching Water to Alleviate Eutrophication of Lake Dianshan and its Benefits

Trying dispatching water from Yangtse River, especially in the period of low period when the lake Dianshan's water quality was the worst. Using water from Yangtse River whose quality was better to dilute water of lake Dianshan，increase the input of lake water and velocity of flow water，increase the water's washing rate，decrease the lake water's resorting time，increase the output of load of pollution and enhance the water quality.

1.1 Dispatching water trial

When The eutrophicatin level of lake Dianshan was deepened and the water quality of Huangpu River was worsened, water was dispatched from the Yangtse River to relieve the eutrophication level of lake Dianshan. On the basis of dispatching water trial from the Yangtse River, when opening six floodgates to dispatching water in summer along the Yangtse River, the water volume that had been dispatched in 25 days was $6.03 \times 10^8 m^3$, the water volume that had reached the lake Dianshan and Dianfeng （on the downstream of lake Dianshan）was following:

（1）water volume dispatched from Liu River floodgate was $2.19 \times 10^8 m^3$, those form all the other 5 floodgates was $3.85 \times 10^8 m^3$. In fact, the flux reached the upper reaches peaks of Huangpu River was only $0.53 \times 10^8 m^3$, which occupied only 8.7% of the total water volume dispatched from the six floodgates of Yangtse River.

（2）when water was dispatched, the water level was moved up 0.10m, when it was concerned that about –0.2m water was consumed due to evaporation, the actual water volume reached lake Dianshan was $0.70 \times 10^8 m^3$, which occupied 12% of those volume dispatched from Yangtse River and 31% of those from Liu river.

According to the monitored data of lake Dianshan's water quality, the concentration change of TN and TP before and after water dispatched from Yangtse River (table 1) .

Table 1 The concentration contrast of TN and TP in lake water

Items	TP（mg/L）	TN（mg/L）
Before dispatching water	0.181	1.10
After dispatching water	0.176	1.09

Drawing water had enlarged the velocity of flow of most of tributaries. and increased the input of lake water, the waterpower-eroding rate had been enlarged and the detained time of lake water had been reduced. The export capacity of pollutant load had been enlarged too.

Dispatching the water, whose quality was better, can also act to dilute the water of lake Dianshan to some extent during the low water season, improve the water quality of lake Dianshan and prevent the further development of eutrophication of Lake Dianshan.

1.2 the cost of dispatching water

（1）the direct economic cost:

The total time of dispatching water was 25 days (7.22–8.15). The data such as floodgate dam worker number, annual repairs and water damaging project cost was consulted the materials provided by the Nanjing Wudingmen floodgate dam.

①The six floodgates' worker's payments and management expenses were 240 thousand yuan. Among them the worker's payments, which were accounted by the standard that 24 men each floodgate, 50 yuan for everyone every day, was 180 thousand yuan. The management expenses were 1/3 of the worker's payments. Approximately it is 60 thousand yuan.

②The annual repair fee of every floodgate was 100 thousand yuan per year. The section consumed during the dispatching water period was 30%. The total amount of the six floodgates was approximately 180 thousand yuan every year.

③Other water damaging project costs was 84 thousand yuan

The direct economic cost of dispatching water was 50.4 ten thousand yuan.

（2）The indirect lose cost

Dispatching water from the Yangtse River had raised the water level of network of waterways Yangcheng Area, created unfavorable influence to the crop output in the beach of river and lake and in the lowland area. According to the material of Suzhou land use, reed area among the water area was about 30 thousand Mu, and about 1/10 reed area had been influenced when dispatching water then the estimated loss cost reaches 300 thousand yuan.

Thinking of the real gained water volume in Lake Dianshan, the totle cost of dispatching water to lake Dianshan was: 50.4×12%+30=36.1(ten thousand yuan).

2 Planting Aquatic Such as Bitter Grass to Prevent and Cure Eutrophication of Lake Dianshan and its Benefits

2.1 The water plant provided measures to prevent and cure the eutrophication of lake

By means of absorbing of water plant, and drawing out the water plant from the lake, the content of nitrogen & phosphorus can be decreased and the developments of eutrophication can be prevented and cured.

（1）the main auqatic of Lake Dianshan and its developement

On the basis of measurement of nitrogen and phosphorus content in the aquatic of lake Dianshan, among the 7 kinds of major sink water plants, the black algae had the highest N content, the same as the document had reported. The fox tail algae had the lowest nitrogen component, the average nitrogen content was 3.02%. The hornwort had the highest phosphorus content, the lowest was the leaflet eye vegetable, The average phosphorus content was 0.37%(table 2).

Table 2 The N and P content in Various aquatic of lake Dianshan

Items	The nitrogen capacity（%）	The phosphorus capacity（%）
Bitter grass	2.67	0.30
The black algae	3.85	0.52
The horse eye vegetable	2.93	0.34
The Leaflet eye vegetable	2.72	0.16
Curly pondweed	3.70	0.36
The fox tail grass	1.86	0.28
The hornwort	3.43	0.63
Average	3.02	0.37

The vascular bundle plants in water such as bitter grass were the important component of lake ecosystems, and it held an important position in the system function. But along with the development and utilization of Lake Dianshan, the diversity and output of the lake had been clearly reduced. The particularly heavy destruction was put on the sink water plant (Table 3).

Table 3　Sink water plant distribution area and biomass of lake Dianshan (net weight)

year	Distribution area(km^2)	Percentage of the whole lake（%）	Assemble biomass
1985	35.66	57	5072.30
1987	37.85	61	5580.77
1988	34.66	56	6173.30
1992	26.04	42	—
1995	24.28	39	4237.56

* Assemble biomass = biomass in lake + harvest

In 1983–1985, bitter grass had the absolute superiority among sink water plant, and especially in the south of the lake, it was almost the most excellent community, and its biomass was the greatest. In 1988–1995, owing to the change of water environment, the distribution area of bitter grass was gradually reduced and its biomass descended too. One of the causes was the reduction of lake water transparent degree. So the amount of light that penetrate into the water reduced greatly. But the growth of bitter grass had a close connection with the transparent degree. The greater the transparent degree, the more the biomass. The bitter grass had fresh and tender leaf, and it was the good bait of fish, and can do the good forage of fowls and livestock such as duck and pig.

But at now the superiority aquatic were the horse eye grass and the black algae (Table 4). Though these two kinds of plants all had some ability to remove nitrogen & phosphorus, but they were not ideal kinds if we considered from the aspect of multiple use of water grass resources. The horse eye grass was unfavorable to fish and can not be changed into fish output. It had a fast grow speed and would cover the illumination for other plants. Other sink water plants had been restrained. Owing to its long and thin stem directly stretched to the surface of the water, it brings the unfavorable influence to the shipping. Therefore the horse eye grass must be controlled so that the bitter grass can grow and be recovered gradually.

Table 4　The monitored biomass of various sink water plant of lake Dianshan (net weight)(t)

Items	The horse eye grass	Black algae	Bitter grass	Leaflet eye grass	Curly pondweed	others
Biomass	1285.44	1060.04	343.56	182.06	152.91	133.55
%	40.71	33.57	10.88	5.77	4.84	4.23

（2）the indexes of recovery and its measurements

If the Sink water plant can be recovered to the highest standard. Its distribution area was about for 37.2km^2, 60% of the total lake. It was estimated that the total biomass of sink water plant was about 5,500–6,600t(net weight). If counted by the average value of nitrogen and phosphorus content in all sorts of sink water plants in lake Dianshan, which are 3.02% and 0.37%, the sink water plant can accumulate nitrogen 166.10–199.32t, phosphorus 20.35–24.42t after the recovering.

Several measures should be taken in order to make the lake have the water plant throughout the year.

①adjusting the community structure to recover race and the community with good quality. Consolidating the two layers of community in the perpendicular distribution, fully using the water body space, developing those kinds that grows in winter. It was needed to draw out of all the horse eye vegetable from the lake, spry the curly pondweed seeds or its buds, make the community which was chiefly the horse eye vegetable change into the community which had two layers in perpendicular. The upper layer was dominated by curly pondweed, the lower was dominated by bitter grass, and make full use of the water space and time. Owing to curly pondweed was a typical sink water grass sprouting in autumn and living through the winter, its biggest biomass appeared in April. Therefore by way of adjusting the community structure, the appearance that there was no water grass in winter can be changed. The water plant can absorb nitrogen & phosphorus in the lake water all the year. The worst condition of water quality would be able to improved in winter.

②To prevent excessively concentrated reap, it should be carried out in batches and by stages on the basis of sink water plant's growth speed. From the end of June to the beginning of July 15% was reaped, from the middle of July to the end of August, 50% was reaped. September was 20%, October 15%. The function of improving water quality of water plant can be made full use to move out nitrogen and phosphorus in the lake.

③To recover the sink water plant area step by step, it was necessary that there are enough breeding bodies. At the same time improving those unsuitable fishing tackle (such as tools used to catch small clam living in fresh water). Making the subterranean stem and bud body of water plant can live through the winter safely.

Strengthen Management; strictly control the frequency and scope of clam catching in lake in autumn and winter. Carry out breeding clam in suitable places and protect the water and grass resources.

If there were enough breeding bodies, in addition with the fulfilling of strict management and concrete measures, it was hopeful to recover the area of sink water plant gradually. Because the root of sink water plant can make loose silt fixed. The sink water plant had luxuriant branches and leaves, it can move out plenty of nitrogen and phosphorus, Make the pollutant change into resource. At the same time, the turning silt by stormy waves water flow and ships had been weakened. It was good to improve the transparent degree and prevent the lake eutrophication. It can Make the lake Dianshan recover into a water ecosystem with reasonable structure and complete function gradually.

2.2 The benefits analysis

（1）investments

①The fee to adjust the structure of community

Because the measures to be adopted was chiefly the biological measures, in order to take on the organized and schemed reap action, a certain amount of management fee and worker's payment was needed. The total investment was estimated as follow:

To Change the horse young eye vegetable into curly pondweed and bitter grass community in the east lake area, the horse young eye vegetable should be dragged out completely then cast into curly pondweed seeds or buds. It was estimated that the biomass was about 8,000t(fresh weight), 500 number ships were needed to remove all of them. Counted by 50 yuan per ship, the ship fee was 25 thousand yuan. Counted as 25 yuan per person, two person per round, worker's payment was 25 thousand yuan. Added with some incidental expensed, the total fee was 55 thousand yuan.

②The fee of operateing

The operating fee: the total biomass of the sink water plant after recovery was 8,000t(fresh weight). Counted as the rate of dry weight and fresh weight of bitter grass was 0.053, the fresh weight was about 1.14×10^5t. According to the fee estimated above, Moving out of the lake need 800 thousand yuan.

③The fee of patrol and management

In the growing period, to avoid unorganized dragging and to avoid excess catching shell and snail in November and December, to protect that the bitter grass and curly pondweed can live through winter safely, The lake surface patrol need be strengthened. According to 2 boats every day, 200 yuan per ship, about 72 thousand yuan was need from June 15 to December 15. If added with 1.8 ten thousand yuan material fee and 5 thousand yuan incidental expenses, 95 thousand yuan was needed totally.

The economic benefits: reaped water grass can be used as forage. Its value was 0.2 yuan per kilogram (net weight). The gained economic benefits was 1,200 thousand yuan. After deduct the investment and operating fee, the net benefit was 250 thousand yuan.

3 Breeding Fish to Prevent and Cure Eutrophication and its Benefits

Effectively making the bait resources in Lake Dianshan overall and reasonably change into aquatic products can not only lighten the eutrophication level of lakes but also obtain some economic benefits.

According to the characteristics of structure and function of the natural bait biological community in lake Dianshan, especially property that plankton and detritus are rich, applying the ecology principle, by way of adjusting the water body food chain structure,. Controlling the herbivorous fish, and developing the community of the strain fish, the Polyphagia fish and breeding the natural economic fish colony, multi kinds and multi scales of fish mix-raising should be carried on.

Besides mix-raising, the produce potential of every fish community should be considered. It was an important measure to exert the produce potential of the water body and fish races of lake Dianshan fully and utilize the natural fish bait reasonably to enlarge the fish output and lighten the eutrophication level of water body.

3.1 Breeding chub and bighead carp chiefly, raising herring and crucian together

Chub and bighead carp are strain fish feeding with the plankton, the density of zooplankton and phytoplankton in the water body can be reduced by them. The regeneration of nutrition in the lake system can be quickened by those fish's metabolism process. The sediment of nutrition also reduced. The herring was a kind of carnivorous fish. The carnivorous fish of Lake Dianshan chiefly feed on small wide miscellaneous fish. To some extent, the excessive proliferation of small wide miscellaneous fish had been restrained. It is favorable for some nutrition, such as N and P, to arrive to the top level consumer fish(carnivorous fish)alone the food chain. Fishing and removing those small wide miscellaneous fish out of water body prompt the amelioration of water quality. But the herring's excreta had the fertilize effect on water body if herring was raised solely. The crucian was the omnivorousness fish. Besides feed animals Perch at the bottom of water body, it can partly remove the suspend granule.

The aim of raising chub, bighead carp chiefly and mix raising herring and crucian was to make full use of the plankton and detritus in the water body. At the same time, it can remove the sediments in the bottom of water body, alleviate the eutrophication level of water body.

On the basis of the results that were gained from the analyses of the relationship between the extant bait resources in the lake and the aquatic product potential, combined the season change characteristic of the bait resources, the fish cultivating quantity mentioned above in lake Dianshan was respectively:

Chub 159kg/hm^2, bighead carp 106kg/ hm^2, herring 21kg/ hm^2 and crucian 18kg/ hm^2. Cultivating area was about 30km^2. The average fish fresh weight was 200–300g.The weight can increase 2–4 times in fishing season. The fish's moisture content was 70%–75% and N/net weight (%) =13.2 and P/net weight(%)=0.94, according to above data, it was estimated that 99.32t N and 7.07t P can be removed by breeding fish.

3.2 Developing the river crab breeding and breeding crab together with fish

Water grass of the Lake Dianshan was just assuming the trend of fading at present. For lightening pressure to water grass, the foster of herbivorous fish are unsuitably in recent years in lake Dianshan. At the same time, thinking of effective utilization of the output of water grass, and creating higher economic value, it was suitable to develop the river crab breeding with some chub, bighead carp, herring and the crucian raised together. In the water body multi-dimensions ecological potential, the priority aspects to be considered was the living space of river crab and its nutrition requirement. The operating way was that every 15m^2 surface of the water 1 young crab was thrown into water. After half year's growth, it can grows to 150g. Think over the confinement of the resources, the breeding area was 13% of the total lake area. It was about 8km^2. The moisture content of crab was 50%–60%, the average value of the net weight rate of nitrogen and phosphorus was used, which was N/net weight(%)=1.355 and P/net weight(%)=0.0,475, according to above data, the crab can carry nitrogen 6.59t and phosphorus 0.23t away every year.

3.3 The utilization of small-size wild fish resources

In the lake Dianshan the small-size wild fish was not various but also fairly rich. According to the statistic data, the extant capacity of small-size fish was about for 27kg/ hm^2. Owing to the fact that the race reproductive capacity of small-size fish was higher and they are preyed by carnivorous fish in the lake, Its production output was more than this data. Though the carnivorous fish's species, which use the small-size fish as bait, was many, its output was low. Thus it can be seen that except a small amount of resource had been changed into carnivorous fish, most of all do not get the very good utilization. The existences of a large number of small-size fish have consumed a large number of bait resources in the lake and compete food with the many economic fish at the same time, therefore the small-size fish resources must be fully used. But it was hard to apply fishery management effectively due to the big surface of lake Dianshan. In the process of fishing small-size fish, The economic fish' seeds also suffer serious destruction. Enlarging the carnivorous fish races suitably, or organized and schemed fishing small-size fish to raise famous and precious aquatic products such as river crab, mandarin fish and soft-shelled turtle in the lake area, was the feasible means to utilize the small-size fish resources and enhance the economic benefits. At the same time too much nutrition matter in the lake can also be removed and the eutrophication level can be lightened.

3.4 The utilization of carnivorous fish

Owing to the fact that the carnivorous fish are often in the top level of water body food chain, the energy change rate was low, they were once looked as the clearing away object. Recent years along with the development of market economy, these fish possess higher food value and receive welcome of consumers. These fish can prey middle small-size low nature fish in the water body. Therefore using these high quality fish, and raising them together with the crab was favorable to develop the high quality and high efficiency fishery.

The kind of carnivorous fish such as the mandarin fish, Mongolia white, snakehead, Nian and yellow forehead fish was more. But what the output was comparatively high were mandarin fish and yellow forehead fish. Other several kinds still have the bigger development latent capacity.

3.5 Strengthen the breeding protection of natural economic fish

The crucian is an important natural economic fish. It occupies 38% output of natural fish in the lake Dianshan. Even if the per unit area yield is in a lower level, such as 22.5kg/ hm^2, it still has the bigger latent capacity to increase production. Because the crucian is easier to capture in spring and winter, fishing should be forbidden in that season in order to protect more colony laying eggs and to increase resource in the winter. The fishing intensity can be suitably increased to a certain degree to enhance the output without influencing the resources regeneration abilities.

Mandarin fish is another important natural economic fish in lake Dianshan. Because its most output comes from 4–6 month, and mandarin fish is breeding at the same time, exorbitant fishing will endanger the supplement capacity of mandarin fish. This is unfavorable to the output of next year. Therefore the appropriate fishing intensity can make mandarin fish resource to be utilized sustainable. The fishing period is shortened to 1–2 month in breeding season and fishing is arranged after its laying period, the supplement of mandarin fish can increase a lot.

3.6 The benefits analysis

The chub, bighead-herring, crucian breeding type—chub and bighead carp as the main species which are good for curing lake Dianshan's eutrophication, herring and crucian as the additional species which take the abundant benthons and detritus as food and create economic benefits—is especially good for mitigating lake Dianshan's eutrophication level and improving the water quality for the follow-up breeding schemes.

The investment was used mainly to buy the fish specifics such as the chub, bighead, herring and some management expenses. It was suitable to be used in the whole lake Dianshan area. The investment of such scheme was about 6,000 yuan per hectare of breeding surface, the rate of input and output was about 1：2.5, that was: if the input was 18,000,000 yuan, the output was 45,000,000 yuan. For crub-fish type, the investment was 932 yuan per hectare, the rate of input and output was 1:3.2, that was: if the input was 74.56 ten thousand yuan, The output was 2,385,920 yuan. The total investment of every year was 18,745,600 yuan. The economic benefits was 47,385,920 yuan. The net profit was 28,640,320 yuan.

In order to evaluate the benefits of the three internal environmental eutrophication prevention and cure measures mentioned above fairly, the indexes such as the TN decrease rate, TP decrease rate, total investment, the operating fee, economics benefits are calculated by the model of gray interrelated synthetical evaluation. The result was: planting grass was the best measure, breeding fish was the better, dispatching water was also good.

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Environmental Dredging for the Treatment of the Inner Source of Pollution in Lakes

Liu Huiqing
Tianjin Waterway Bureau, Tianjin 300042

Abstract The article states the necessity of environmental dredging in treatment of the inner source of lake pollution, the development of environmental technology and equipment, the environmental dredging practice in our country and suggestions for the future.
Key-words Lacustrine Eutrophication Inner source Environmental Dredging technology

Introduction

The freshwater resources per capita in China are less than 1/3 of those of the world, in which those from lakes account for about 70%. Along with the rapid development of agriculture and industry and the course of urbanization, eutrophication in lakes becomes worse, which directly concerns the living environments of the Chinese nation in 21st century. Eutrophication in lakes and its prevention is a worldwide multiplex crux, to confront it is a mission entrusted to environmental scientists by history and high concern in this aspect has been aroused in the dredging circles of China and the world.

At present research and regulation of water environment is being carried out in the country with emphasis put on the 3 lakes (namely Chaohu, Taihu and Dianchi). While the outer sources of pollution of the lakes are controlled, the treatment of the inner sources of pollution is being strengthened, which includes dredging and disposal of contaminated subsoil, ecological restoration in lakes and improvement of water quality. In the field of dredging and disposal of contaminated subsoil we have successively made the feasible studies and designs for the dredging and treatment project of contaminated subsoil in Caohai of Dianchi and Chaohu where the pollution is considered serious. We have completed Phase I Project of Dianchi, we're doing Phase I Project of Chaohu and removing contaminated subsoil of Shiwuli River in Hefei, and we're to start the extension works of Phase I project of Dianchi.

The science of water environment is a comprehensive one that involves many subjects. Eutrophication in lakes and its prevention is a wide-covering and systematic work. To deal with the many important questions in basic science existing therein and the problems in practice, common efforts of scientists and engineers from the world are needed in research and getting the settlement.

1 Necessity in Dealing With Contaminated Subsoil in the Treatment of Inner Source of Pollution in Lakes

Lacustrine sediment is the major store for nutrient salt. Discharge of sewage, inflow of surface runoff and remains of aquatic life would result in progressive accumulation of nutrient salt in lacustrine sediment. Especially in the city lakes an internal load of nutrient would be brought about. In our country the total content of phosphorus in city lakes can be as high as 1,227.6—4,504.7ppm. And in Chaohu the annual release quantity of phosphorus can be up to 220.8t which amounts to 20.9% of the yearly phosphorus load entering the lake. After the outer source (surface and point) of pollution is reduced or completely intercepted, the nutrient salt deposited in the pollutant at the lake bottom will be released to replenish the lake water, which tends to give rise to eutrophication even "water bloom". It is clear that under certain conditions nutrient salt in sediments can be a primary factor for eutrophication in lakes. As is stated in the "Guidance of Environmental Investigation in Lakes" of Japan, "In shallow and overnutritious lakes the role of the bottom can not be neglected in determining the key factors which affects water conditions." For the circulation of nutrient salt in lakes see Figure 1.

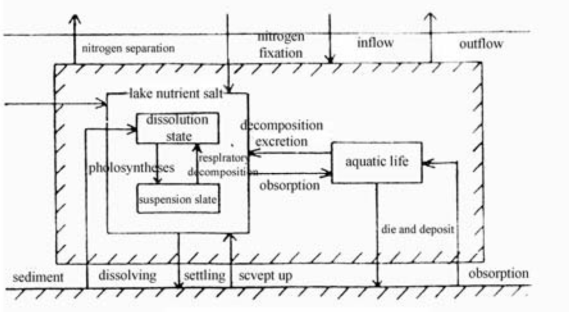

Fig. 1 Cireulation of Lake Nutrient salt

Contaminated subsoil in lakes mainly comes from the runoff with pollutant discharged into them. Its distribution law conforms to the principles of fluvial dynamics, lacustrine dynamics and sediment kinematics on the whole, all of which are generally the combinations of hydraulics and sediment characteristics. Now the research of environmental hydraulics drives to provide more scientific methods. As to the effects from physical, especially chemical and ecological, reactions of current, sediment characteristics and various pollutants, it is a more complicated subject. In Caohai of Dianchi and Chaohu the distribution of contaminated subsoil accords with the basic law of estuary sedimentation. To deal with lake contaminated subsoil refers mainly to the entrance areas of runoff with pollutant and the runoff channels and ditches with seriously contaminated subsoil, such as the estuaries and riverbeds of Yunliang River, Xin River, Wangjiadui Canal and Chuanfang River of Dianchi and Huancheng River, Zhegao River, Shiwuli River and Nanfei River of Chaohu. In lakes the contaminated subaoil will move under the action of current, e.g. in Shiwuli River of Chaohu with the inflow of a large amount of pollutant a severe pollution zone has taken shape from northeast to southwest down to the intake of The 4th Water Works of Hefei. Another case is that in Caohai of Dianchi yearly dead hyacinth after overgrowing will deposit to the bottom and change into corrosive organic substance after rot which causes pollution to a large area.

Many experiments and research show that the pollution level of sediment primarily depends on the mean grain size. The smaller the mean grain size is, the higher the contaminability or the adsorbability for pollutant. Principally the surface area of fine grain of sediment is much larger than that of coarse grain and the logarithmic relation curve between sediment grain and its surface area is give in Figure 2. Moreover, fine grains have the characteristics of small critical pickup velocity and easy suspension and dispersion which shall be particularly taken care of in dealing with contaminated soil and environmental dredging.

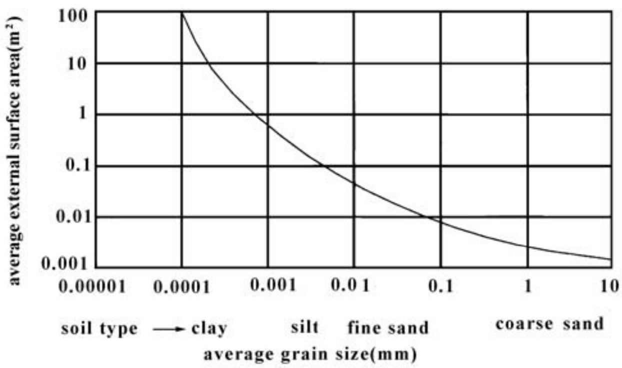

Fig. 2 Relation between Grain size and Its Surface Area (per kg)

2 Development of Environmental Dredging Technology and Equipment

The worldwide protection and regulation of water environment, especially the lacustrine contaminated sediment is opening an environmental dredging market. This market shall lead the development of environmental dredging technology and equipment.

Lake contaminated subsoil is part of the inner source of pollution. Our purpose is to make pollutants neutral to the environment, not thoroughly eliminate them. There are many ways in treating contaminated subsoil. If there’s enough water depth we may cover it up with clean sediment making it isolated from its surroundings. There’s another possibility, though not yet well proven, that we can neutralize or fix the pollutants in subsoil. In other cases dredging might be the only way to get rid of the contaminated subsoil, i.e. have it properly removed and disposed of . Dredging companies are removers of contaminated soil, they are not pollution distributor. When we engage ourselves in environmental dredging, we must try our best to make the execution meet the requirements set by environmental scientists. To realize it we must have the knowledge about environment and use it to regulate our working process and activities. This knowledge cannot be superseded by ordinary dredging experiences. The environmental dredging is different from the ordinary one in the following respects:

（1）It’s not for opening up water area of certain measurements, but completely for removing the contaminated subsoil. The excavation scope depends on the distribution of contaminated subsoil. And measures shall be taken not to excavate the non-polluted soil layer.

（2）Higher accuracy in horizontal positioning and depth control is required and the dredged section shall be kept as much as possible to tally with the distribution of contaminated subsoil.

（3）Measures shall be taken in the light of pollutant properties and secondary pollution due to the dispersion of pollutant in water during excavation shall be minimized.

（4）Leakage in transportation is not allowed. In the process of disposal pollution to the surroundings and subsurface water shall be avoided. And when the soil is transported by discharge pipeline the discharge of surplus water from the pond shall be controlled to the standards.

（5）It is required that the volume concentration during execution be as high as the technology allows so that both the surplus water and handling volume can be reduced.

（6）The dredging equipment and construction methods shall be specially designed and they shall be accepted technically and environmentally.

（7）For the subsoil with serious contamination (such as containing a large amount of noxious heavy metal, toxic organic matter and so on), if the work quantity is big enough, the dredging equipment with higher scientific and technical content shall be purposely designed based on the study of the works conditions. Only in common cases the environmental dredger or reformed ordinary dredger shall be adopted.

（8）Special monitoring measures are necessary.

（9）Contaminated subsoil is usually in sludge state. When more organic matter exists, it sometimes presents colloidal state, while the power of dredging equipment is comparatively small and the rotational speed of cutter low. Optionally scraping suction or direct suction can be used instead.

（10）The cost of environmental dredging is much higher than that of ordinary dredging because of costly equipment, limited output and complex processes. In the world market the unit rate for environmental dredging can be several or ten odd times that of ordinary dredging.

Furthermore the work procedure of environmental dredging is more complicated than that of ordinary one, too.

Up on the demands of environmental dredging market assorted environmental dredgers have come into being. Most of these dredgers are of small and middle sizes and those likely used in rivers and lakes are cutter suction dredgers built with high and modern techniques, the technological development of which is relatively faster. There are also more projects of dredging contaminated subsoil in lakes, where the cutter suction dredger is the principal force. Generally speaking environmental dredgers are designed by large dredging companies of solid strength in line with specific working conditions and then built by shipyard. In some cases ordinary dredgers are reformed to meet environmental requirements.

At the moment the advancement of world dredging equipment and technology aiming at environmental dredging presents itself in the following aspects:

⑴ Increase accuracy (horizontal and vertical)

① Reliable DGPS is adopted to increase horizontal accuracy and installed on the dredger.

② Establish accurate stage automatic telemetering system.

③ Increase the accuracy of depth indicator on dredger.

④ The spud carriage system is adopted on the cutter suction dredger.

⑤ PC and sensor are made use of to display construction parameters and exact positions of the concerned parts of a dredger.

⑥ Set up electronic graphic system and 3-dimensional numerical model of contaminated subsoil, added screen display to enhance the accuracy of construction.

⑦ The distribution of contaminated subsoil in excavated section and the actual position of cutter head are displayed synchronously that the construction is visualized.

⑵ Develop and improve excavating equipment to minimize secondary pollution in the process

① Disk Environmental Cutter Head: Excavated soil is enclosed in the protective hood and the circular cutter head may cut thin mud layer with high accuracy.

② Blading and Dragging Suction Dredge Head: Given that the water content is high and natural unit weight low in contaminated subsoil, the dredge head has no rotating device, taking subsoil and sending it to the suction inlet by way of a steerable scraper or scraper pan with less turbidity, higher concentration and accuracy.

③ Auger Cutter: On the two sides of the inlet the two parts of auger rotate differently to facilitate subsoil going to the inlet via spiral chute. Then the submerged pump suctions and discharges the soil, concentration being rather high. Since the auger cutter can be adjusted horizontally and vertically, high planeness can be achieved.

④ Squirrel-cage Cutter Head: There’s a hermetic cover on the top and the cutter head consists of rotating squirrel-cage blade and a fixed cone with spiral soil-diversion vane, the cutting thickness of which is below 30cm. This is a kind of cutter-head with better adaptability and slightly improved it can be put on an ordinary dredger. The first environmental dredger “Jun Hu” recently imported in our country is equipped with such a cutter.

⑤ For grab dredger, the grab can be designed as totally enclosed anti-leakage one. After taking contaminated soil, it will close automatically to prevent leakage as it is being lifted from water. To raise the excavating planeness it can be designed as a horizontal grab.

⑥ When bucket dredgers are used in dredging contaminated subsoil, the buckets are usually remolded as can be enclosed so as to minimize secondary pollution.

⑦ To have a higher concentration of dredged contaminated soil, the topic of “undisturbed soil dredging” has been put forward in dredging circles, the purpose of which is to excavate and transport undisturbed contaminated subsoil with only necessary amount of process water.

As a matter of fact strict requirements in accuracy and excavation limits of environmental dredging set up many technical barriers to the dredging circles, such as at different positioning points requiring different dredging depths, at an irregular cross-section removing contaminated sediment in a controllable way. This is an uncommon dredging work and it can be realized only on thorough automatization of dredging system, i.e. the dredging process operated and controlled by computers. Lately some dredging experts abroad advanced the “fundamentals of digital dredging” and are having them improved and perfected, which has a good prospect. Using digital dredging to gain the diggability and removing of contaminated sediment means not only the reducing of dredging quantity but also the decrease of contaminated soil volume to be treated and stored, which may benefit the employer in saving considerable cost. This new technique shall be first applied to cutter suction dredgers.

3 Dredging of Contaminated Subsoil in Caohai of Dianchi and Chaohu

Caohai is situated in the north part of Dianchi and southwest to the environs of Kunming. It is the place where the industrial waste water and sanitary sewage from the city is discharged, annual sewage discharge being up to 70 million odd tons, silt 97,500t. It is the heaviest polluted water area in Dianchi, arsenic and heavy metals like Pb, Cu, Cd and Zn being deposited and posing latent ecological damage. In the whole water area of the lake arsenic is in such an intense or very intense state that the ecology there is in danger. In the contaminated subsoil the contents of TN and TP are high, N being 0.63%–2.43% and P 0.04%–0.41%, which causes exceptional eutrophication. Blue green algae and hyacinth overgrow and emerge and perish of themselves. The water there is black and stinking and Caohai is on the verge to become a quagmire. For the physico-mechanical indices and pollutant content of the contaminated subsoil in Caohai, Dianchi see Table 1.

Table 1 Physico-mechanical Indices and Pollutant Content of Contaminated Subsoil in Caohai of Dianchi

Soil type	Specific gravity	Natural density (kN/m^3)	Natural water content (%)	Liquid limit W_L(%)	Liquidity index I_L	Plastic limit W_P(%)	Void ratio e	Cohesive force $C(K_{Pa})$	Internal friction angle ϕ (°)	Soil state
Silty mud	2.23	11.40	394.60	244.20	1.88	148.60	7.51	5.01	3.75	Flowing plastic
Peaty soil	1.83	10.50	458.70	368.90	1.83	246.10	9.04	5.70	3.70	Flowing plastic
Silty clay	2.48	14.90	88.99	75.20	1.39	45.40	2.20	7.40	4.20	Consistent soft plastic

Particle size range	0.5～0.25	0.25～0.075	0.075～0.05	0.05～0.01	0.01～0.005	<0.005
Content (%)	31.0	7.0	24.0	19.0	7.0	12.0

Pollutant	TN	TP	Cu	Pb	Zn	Cd	Hg	Cr	As
Content	39,600	7,900	1,475	624	2,874	143	2.1	457	Certain amount

Chaohu is a lake of the most severe eutrophication in our country, especially the part in the vicinity of Hefei and Chaohu cities. As a large amount of industrial wastewater and sanitary sewage discharged into it accumulates unceasingly and pollutants disperse all the time, the water quality at the intake of water works is immediately threatened. This has caused several water works put out of service, domestic water of the local people strained and the development of the city retarded. The works of dredging and disposal of contaminated subsoil in Chaohu began from the heaviest polluted areas near Hefei City and Chaohu City, key points being the estuaries of Nanfei River and Shiwuli River close to Chaohu City. Simultaneously dredging in Shiwuli River of Hefei, Huancheng River of Chaohu and nearby areas of water intakes of the cities was undertaken. The layer of severe contaminated subsoil in Chaohu contains a high percentage of nutrient salt, phosphorus content equaling 0.05%—0.21% and nitrogen 0.1%—0.31%.

For the dredging and disposal of contaminated subsoil prospecting, feasible study and design were carried out.

Table 2 Details of Environmental Dredging Works at Dianchi & Chaohu

Project title / IndexItem	Dredging of subsoil at Caohai of Dianchi				Dredging of subsoil at Caohu		
	Phase I	Extension of Phase I	PhaseII	subtotal	Chaohu City	Hefei City	subtotal
Dredging quantity $10^4 m^3$	399.28	156	243.72	799	301.99	414.0	715.59
Dredging area km^2	7.499	2.88			2.111	3.4575	
Construction period	98.1～99.4				99.1～	98.12	

In the execution the following major technology and measures were used:

（1）Work was done by cutter suction dredgers. For reducing secondary pollution a protective hood was installed on the cutter head. By on-the-spot determination the dispersing distance of pollutant in water was within 15m during execution. It shall be deemed that the turbidity was suctioned away on the whole.

（2）DGPS network was made use of in exploration survey of bottom relief and contaminated subsoil and control of ship position in operation. Boundary leading marks were also arranged.

（3）Design of dredge-cut accorded to the utmost with the chart of contaminated subsoil.

（4）At spoil storage yard gravity type geotextile impervious enclosures were constructed. In accordance with the content and nature of pollutant impervious geotextile was not used at the bottom of storage yard, instead the filtration of peat horizon and clay layer was made use of. In the results of water quality determination at monitoring hole there are no obvious signs that underground water is polluted by the contaminated subsoil in storage yards. Leaching tests show that heavy metals in the contaminated subsoil of Caohai, Dianchi can be adsorbed and intercepted by the peat horizon at the bottom of storage yard.

（5）Experiments indicate that the critical quiescent time for surplus water to meet the quality requirements is 46h after the sludge is dumped into storage yard. For this reason 48h must be allowed for the settlement after the yard receiving discharge in execution. At the later stage of project when the volume of storage yard became less and 48h could not be satisfied, contingency measures were taken by putting in chemical agent like PAC to expedite the settlement.

（6）After the contaminated subsoil in storage yard was air-dried for 1–2 months, grass was planted so as to seal off the contaminated soil and restore the landscape. A significant amount of phosphorus and nitrogen is to be adsorbed by the vegetation.

Table 3 Pollutant Content in the Contaminated Subsoil Dredged and Disposed of in Phase I Works at Caohai, Dianchi

Pollutant	TN	TP	Cu	Pb	Zn	Cd	Hg	Cr	As
Content	39,600	7,900	1,475	624	2,874	143	2.1	457	Certain amount

For pollutant contents in Phase I Works of Caohai see the table above. In the execution of the works we became to know by determination that we had removed phosphorus 1,700t, nitrogen 20,000t and heavy metals 5000t. Before dredging the water in Caohai was black and stinking, water quality was worse than the Class-Ⅴ indices of Environmental Quality Standard for Surface Water, COD was3.8 times the Class-Ⅴ index and phosphorus 7.6 times. After Phase-I Works the water body in the dredging area is no longer as before and water quality has evidently taken a favorable turn. Transparency of the water has changed from less than 0.37m to 0.8m. Some key quality indices have locally come up to the standard of Class Ⅲ–Ⅳ. Please see Table 4 for the exact data. At some parts of the water in dredging area waterweeds have grown and some other water plants are found, too.

Table 4 Comparison of Water Qualities in Caohai Dredging Area before and after Dredging

Item	TN (mg/L)	TP (mg/L)	SD (m)	Chla (mg/m^3)	BOD_5 (mg/L)	COD (mg/L)
Per-dredging	10.4	1.19	0.37	240	21	9
Post- dredging	6.61	0.42	0.8	90	12.5	5.6
Increase rate of water quality(%)	36.4	64.7	53.8	62.5	40.5	37.8

By means of comparison and analysis of the environmental benefits of regulation works and subsoil dredging the following conclusions are reached:

（1）After series of regulation works were completed at Dianchi, expected results have not been attained in the improvement of water quality. Since subsoil releases pollutants into water incessantly, pollutants in water are complemented and kept at a higher level, so the effects of outer source regulation works are weakened.

（2）Nitrogen and phosphorus pollutants removed in subsoil dredging are respectively 5.9 and 7.0 times those cut down by outer source regulation works. Subsoil dredging played the most important role in bringing down the total amount of pollutant in Caohai.

（3）After snbsoil dredging the peril of subsoil release is thoroughly removed. Meanwhile the best effects of outer source regulation works have been brought out and water quality of Caohai has been greatly improved.

（4）Subsoil dredging has promoted the restoration of aquatic ecosystem of Caohai.

4 Conclusion, Problem and Suggestion

Based on the development of world environmental dredging and our own practice we put forward the following points of cognizance:

（1）In the treatment of lacustrine eutrophication it is necessary to dredge and dispose of contaminated subsoil which is one of the sources of lake pollution but the outer source of contaminated subsoil must be controlled in advance. In the meantime the contaminated subsoil remaining in contribution rivers and canals shall be properly removed and dealt with. Dredging and treatment of contaminated subsoil are helpful in curing lakes of eutrophication and it is more necessary if the contaminated subsoil is nearby the water intake of city and has immediately made the water quality worsening.

（2）For treating contaminated subsoil there might be many ways, such as physical, chemical and biological. At present environmental dredging might be preferable for its relative economy and functionality.

（3）Modern dredging is an industry of capital and technology concentration. Environmental dredging shall set strict demands on equipment, construction process, accuracy and disposal of contaminated soil, which will definitely incur big increase to the cost of dredging. The fact cannot be ignored. On the other hand the demands in the above respects shall be affirmed carefully in the light of pollutant properties. While lower demands cannot satisfy environments, higher ones costly and wasteful. Once demands are confirmed, they shall prevail in design and construction.

（4）We have gained some experiences in environmental dredging but some problems are existing in practice. In future continuous summing-up of experiences is a necessity so as to drive at standardization and shaping up the provisions with environmental dredging characteristics of feasibility study, prospecting and design, construction and supervision.

（5）The development of environmental dredging in our country should be energetically supported and encouraged. While we are making research and having stipulations on the environmental dredging technology and its quality, the combination of dredging and environmental protection shall be advocated vigorously. Exchanges of cross subjects shall be actively developed to accelerate the progress of environmental dredging technology. Research and adoption of new outcome, new technology, new equipment and new process in dredging industry shall be encouraged to meet the requirements in the treatment of water environment.

（6）Viewing the cases of several projects there are too many obstacles in dredging area, which negatively affects the execution of environmental dredging works. This reflects the weak link existing in the lake management of our country. In this regard protection laws are called for, which shall strictly prohibit dumping or leaving behind fishing tackles and stones. Building of structures which may harm lake ecology shall be strictly prohibited, too, so that the lake environment is safeguarded substantive and effective.

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5 WORLD DREDGING Mining & Construction

6 DREDGING AND PORT CONSTRUCTION

7 PORTS AND DREDGING

8 TERRA ET AQUA

9 Feasibility Study on Dredging and Dispasal of Polluted Bed-silt in Caohai of Dianchi; Feasibility Study on Phase-I Project of Dredging and Dispasal of Polluted Bed-silt in Caohu (by Chinese Academy of Environmented Science)

Ecological Restoration of Shallow Eutrophic Lakes by Drawdown: Concept and Implications for Lake Dianchi (China)

Friedrich Recknagel Mardi van der Wielen
Adelaide University, Department of Soil and Water
Glen Osmond 5064, Australia

Abstract Research at the Pilby Creek wetland (Australia) has shown the potential of annual temporary drawdown for ecological restoration of shallow lakes. Outcomes of this research have been summarised in a conceptual model that may guide lake restoration by drawdown. The conceptual drawdown model is applied to design a scenario for restoration management of the shallow hypertrophic Lake Dianchi (China). It indicates that drawdown may be the key for the ecological recovery of Lake Dianchi after efficient control of its nutrient loading has been implemented.

1 Eutrophication Management of Shallow Lakes

In the last century eutrophication management of freshwater lakes has been put on a scientific footing based upon knowledge about nature and ecology of lakes such as:

- lakes are open systems which are not isolated from their catchment but are very much driven by external loadings originating in their catchments (eg Thienemann 1926; Naumann 1930; Vollenweider 1968).
- eutrophication of lakes is very much controlled by the limiting factors : underwater light, nutrients, grazing by zooplankton. Amongst micronutrients phosphorus proves to be limiting nutrient for eutrophication (eg Sakamoto 1966; Vollenweider 1968; Schindler 1977).
- eutrophication of lakes is no longer a qualitative entity but can be classified into trophic categories oligo-, meso-, eu- and hypertroph by means of measurement of nutrient concentration, phytoplankton biomass, chlorophyll and water transparency (Vollenweider 1968).
- eutrophication of lakes is predictable by means of evolving research in lake ecosystem modelling in order to analyse and synthesise physical, chemical and biological processes (eg Dillon and Rigler 1975; Vollenweider 1976; Bierman 1976).

Based on these findings external and internal control measures are distinguished for eutrophication management of deep or shallow lakes. Figure 1 summarises currently available options for lake eutrophication management. The external control measures in Figure 1 aim at the prevention or reduction of nutrient loadings from point and non-point sources in catchments. The internal control measures aim at physical, chemical or biological manipulations of lake ecosystems.

While external control measures are relevant and most crucial to both shallow and deep lakes, physical measures for internal eutrophication control are relevant only to deep lakes. Some of the chemical and biological measures for internal eutrophication control are only relevant to shallow lakes, others are relevant to both deep and shallow lakes (see color of boxes in Figure 1).

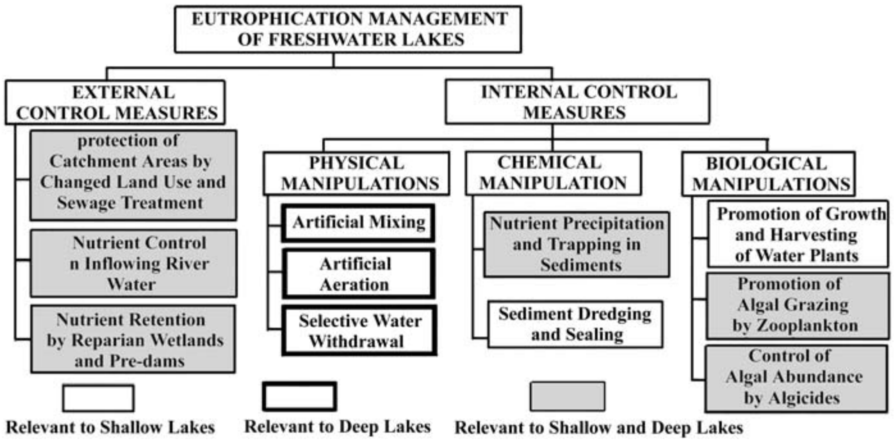

Fig. 1 Options for eutrophication management of freshwater lakes

In the context of this paper the potential of drawdown for eutrophication management of shallow lakes is discussed in order to promote growth and harvesting of higher water plants. After outlining the general concept and possible effects of drawdown as concluded from a case study at Pilby Creek wetland (Australia), a scenario is drawn for the application of drawdown to the restoration of Lake Dianchi (China).

2 Turning Shallow Lakes from Algae to Vegetation Dominance by Drawdown: Lessons from the Pilby Creek Case Study

Drawdown has been suggested in the literature by several authors as an option for lake restoration (Harris and Marshall 1963; Jackson et al. 1977; Fox et al. 1977; Gurney and Robinson 1988; Lubinski et al. 1991; Meridino and Smith 1991). Drawdown can stimulate germination and growth of emergent water plants, sequestering nutrients in their biomass, which can then be removed from the system by harvesting. Complete drawdown and drying can also result in consolidation of sediment, reducing resuspension and therefore improving underwater light and reducing the level of nutrients associated with suspended particles. However, the knowledge base on best practice and ecological effects of drawdown is still fragmentary. Over the last five years we have conducted ecosystem experiments on the restoration of Pilby Creek wetland (Australia) by drawdown. Findings of this research have led to a conceptual model that is detailed below.

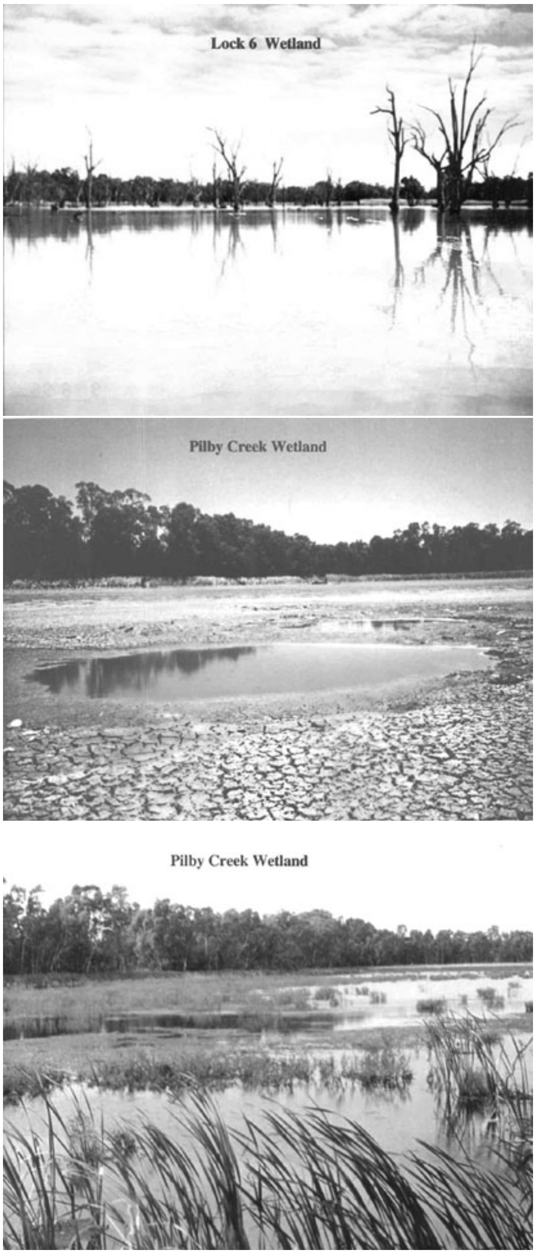

Fig. 2 Views of (a) Lock 6 wetland, (b) Pilby Creek wetland during drawdown in 1996 and (c) Pilby Creek wetland after flooding in 1998.

2.1 Pilby Creek Wetland

Pilby Creek wetland is a naturally temporary wetland in the Chowilla floodplains on the Lower River Murray in South Australia. It has a maximum depth of 1.6 m with a maximum volume of 18,500 m^3 and a surface area of 12.5 hm^2. Like the majority of floodplain wetlands on the Lower Murray, the ecology of Pilby Creek wetland has been heavily degraded in the past 80 years by permanent inundation as a result of flow regulation of the River Murray since the 1920s (Pressey 1986). Permanent inundation suppresses the boom-bust ecology to which the system is adapted under temporary conditions. Furthermore, the permanent inundation has favoured the invasion of common carp, Cyprinus carpio, which has been introduced in the early 1960s and spreads through the Murray-Darling Basin since then. Carp are thought to degrade wetland habitats by uprooting water plants and increasing turbidity while feeding in the sediment (Roberts et al. 1995).

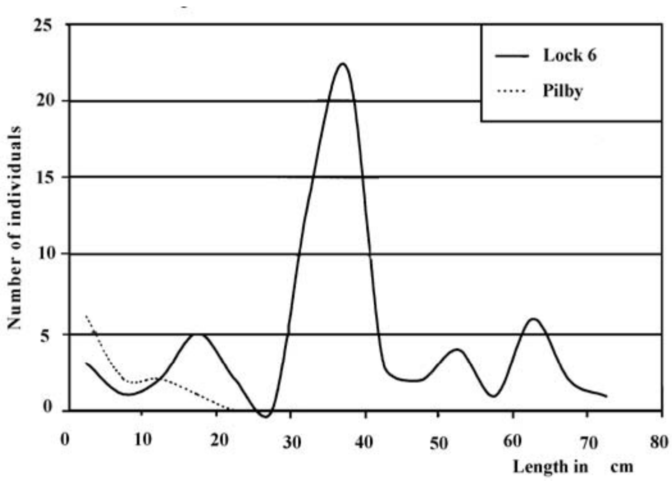

Fig. 3 Size class distribution of Cyprinus carpio in Pilby Creek and Lock 6 wetlands in 1996 (from Recknagel et al. 1998, modified)

In 1995, Pilby Creek wetland was equipped with a constructed inlet which allows control of flow and immigration of adult carp. Since then Pilby Creek wetland has been used as an experimental site for studying the effects of drawdown and carp reduction (see Fig. 2b and c) on water quality and habitat conditions through the use of water quality monitoring and biodiversity surveys (Recknagel et al. 1998). In order to reveal relative effects of these experiments, the neighboring non-controlled Lock 6 wetland (Fig. 2a) was monitored simultaneously.

Figure 3 shows that the constructed inlet has been successful in reducing the abundance of adult carp in Pilby Creek wetland compared to Lock 6 wetland. Small carp are still able to pass through the inlet grill, and adult fish are also able to swim into the wetland when floods overtop the inlet structure. Therefore drawdown needs to be repeated at appropriate intervals to keep the carp density low.

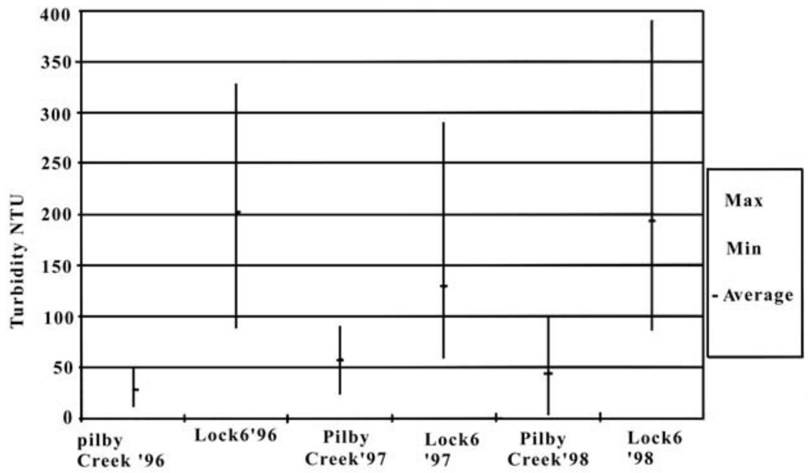

Fig. 4 **Observed ranges and averages of turbidity in Pilby Creek and Lock 6 wetlands from 1996 to 1998 (from Recknagel et al. 1998; van der Wielen, unpub. data)**

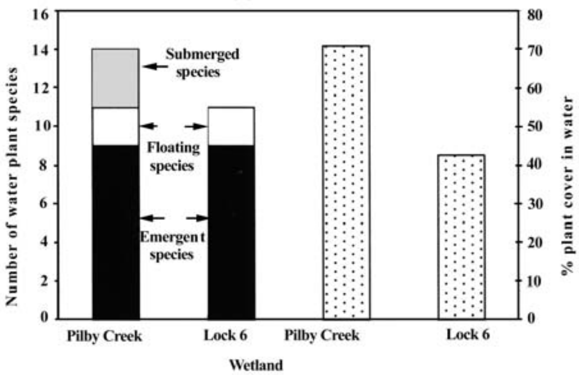

Fig. 5 **Diversity and abundance of functional groups of water plants in Pilby Creek and Lock 6 wetlands in 1997 (from Pfitzner 1997)**

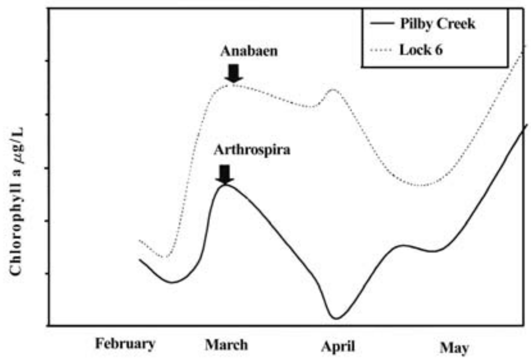

Fig. 6 **Phytoplankton abundance in Pilby Creek and Lock 6 wetlands in 1997 (from Recknagel et al. 1998, modified)**

The turbidity in Pilby is considerably lower than in Lock 6 wetland as shown in Figure 4. We hypothesise that this is due to the combination of increased sedimentation due to lower turbulence as a result of shelter and increased plant growth (e.g. Dieter 1990), reduced carp abundance reducing bioturbation (e.g. Roberts et al. 1995), reduction in resuspension due to drying induced sediment consolidation (e.g. van der Wielen 2001).

Pilby Creek wetland supports a higher diversity and abundance of water plants than Lock 6 wetland as shown in Figure 2 and 5. Of particular interest is the fact that submerged water plants are only found in Pilby (Figure 5). This is likely to be due to the suppression of submerged plants in Lock 6 wetland through the combination of carp action and low underwater light levels. The data shown in Figure 5 was collected in the spring of 1997, nine months after the wetland had been refilled and maintained at a relatively constant water level. Observations made after refilling in

1998 (Fig. 2c) and in 2000 (van der Wielen, pers. obs.) when the wetland was subjected to fluctuating water levels showed a high diversity of emergent amphibious water plants apparently germinating from the seedbank. It is likely that this group of species would be maintained by the fluctuating levels (Brock and Casanova 1997) and so were potentially reduced or absent in the survey conducted in 1997 under constant level conditions.

Measurements on abundance of algae in 1997 indicated that Lock 6 wetland tends to have higher chlorophyll-a concentrations than Pilby Creek wetland (Fig. 6). This is likely to be due to an increased nutrient competition by water plants which results in nutrient limitation of algal growth. A shift in the species composition of algae was observed between Lock 6 and Pilby Creek wetland in 1997 as well (Fig. 6). The noxious blue-green algae Anabaena peaked in Lock 6 wetland to up to 160,000 cells/ml but occurred in low numbers at Pilby Creek wetland (1,000 cells/ml). However, the non-toxic blue-green algae Arthrospira became abundant at Pilby Creek (up to 100,000 cells/ml) as a result of drawdown in 1997. The suppression of Anabaena in Pilby Creek seemed to be due to the inhibition of benthic spore germination by sediment drying (Baker and Bellifemine 2000). Arthrospira does not germinate from benthic spores but prefers humic conditions. The latter is present in Pilby Creek wetland by the breakdown of organic matter from dead water plants of the previous growing season.

The trend of higher diversity at Pilby Creek wetland is carried through for macroinvertebrates as shown in Figure 7. The food and structural diversity provided by the range and abundance of waterplants at Pilby Creek wetland is likely to be responsible for these observations.

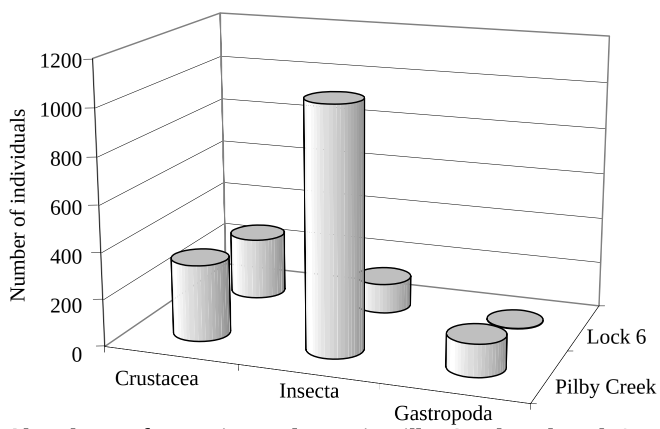

Fig. 7 Abundance of macroinvertebrates in Pilby Creek and Lock 6 wetlands in 1996 (from Recknagel et al. 1998, modified)

2.2 A Conceptual Model for Drawdown of Shallow Lakes

Figure 8 summarises findings from the Pilby Creek case study into a conceptual model for drawdown of shallow lakes. As drawdown aims at the promotion and harvesting of higher water plants, it is suggested to combine it with the control of benthivorous fish if applicable (Fig. 8) in order to prevent adverse effects on water plants such as uprooting. Drawdown can stimulate germination of emergent water plants from the seedbank, which take up nutrients from the environment and reduce the abundance of phytoplankton by competition for light and nutrients, allelopathy and sedimentation of non-motile species. Drawdown can decrease the abundance of noxious blue-green algae such as Anabaena that germinate from benthic spores. Waterplants are also likely to provide shelter for zooplankton, thus promoting suppression of phytoplankton by zooplankton grazing. Predation on zooplankton is likely to be further decreased by the reduced abundance of carp which have been recorded as including zooplankton in their diet (eg. Hall 1981).

Overall the increased abundance and diversity of water plants in shallow lakes is likely to improve the abundance and diversity of aquatic macroinvertebrates and water quality. Blooms of noxious blue-green algae may less frequent. Appropriate harvesting of water plants must be considered in order to prevent the recycling of eliminated nutrients from dead plants.

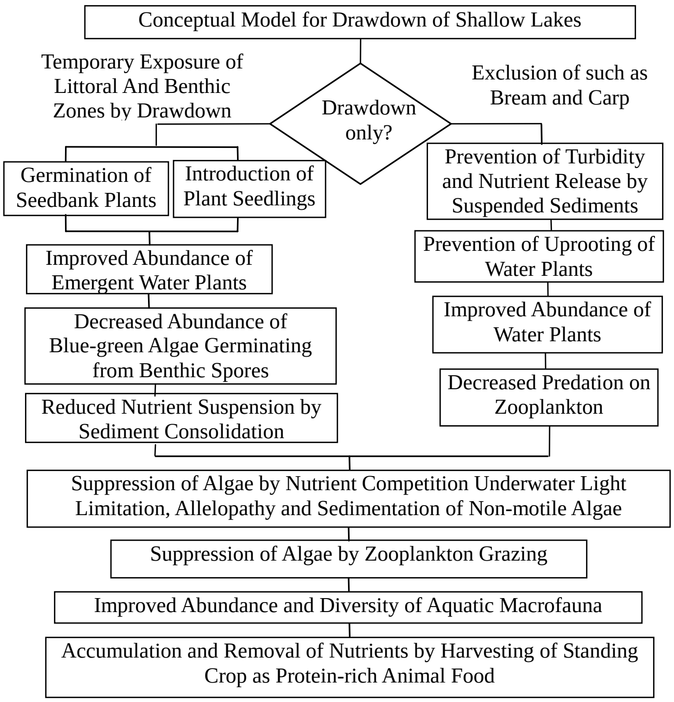

Fig. 8 Potential effects of drawdown on shallow lakes

The Pilby Creek study has shown that the timing is crucial for the success of drawdown and drying. Figure 9 summarises some effects determined by the extent of drawdown and drying. It indicates that extended drying can inhibit aquatic biodiversity and impair water quality by salinisation. Therefore each freshwater system subject to drawdown needs a specific approach depending on habitat and climate conditions.

3 A Visionary Scenario for Restoration of Lake Dianchi

Lake Dianchi is a large plateau lake situated in the Yunnan Province in Southwestern China. Characteristics of its topology and water quality in Table 2 indicate that Lake Dianchi is highly eutrophic and shallow. Shallow lakes belong to the most productive ecosystems on earth driven by external and internal nutrient loadings and almost complete mixing during the year. The ecology of shallow lakes is very fragile and tends to have two stable steady states (Scheffer 1998): (1) the macrophyte state that is characterized by relative clear water, low abundance of algae and high abundance of zooplankton, macroinvertebrates and fish; (2) the blue-green algae state that is characterized by turbid water, absence of submerged macrophytes, and low abundance of emergent macrophytes, zooplankton, macroinvertebrates and fish.

A lake in state (1) can suddenly turn into state (2) by extreme storm events that uproot macrophytes (e.g. Fox et al. 1978), long lasting inorganic turbidity as a result of erosion that limits light, eutrophication as a result of high nutrient loadings, changing water regime and reclamation of littoral areas. However a lake in state (2) can hardly turn back into state (1) without human intervention.

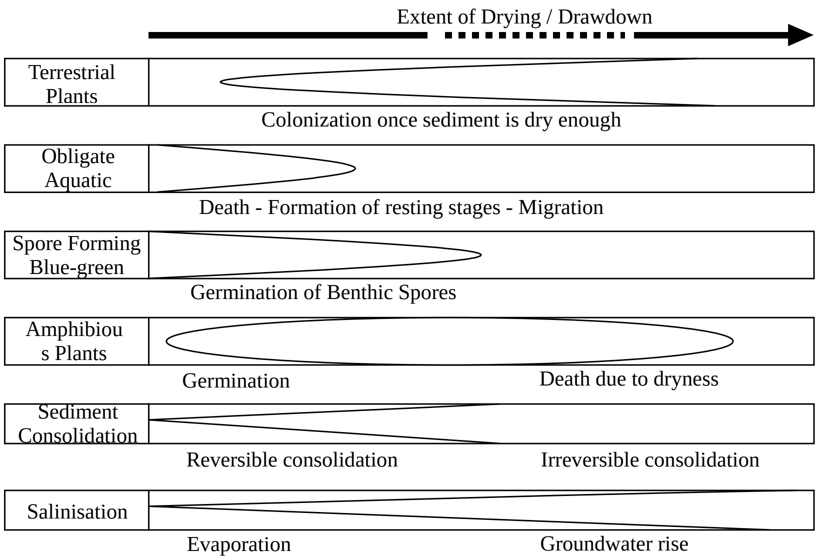

Fig. 9 Potential effects of the extent of drawdown to shallow lakes

Table 2 Characteristics of Lake Dianchi (Yunnan Institute of Environmental Science 1999)

Catchment Area	2,920 km^2
Lake Surface	300 km^2
Lake Volume	1,300 million m^3
Average Depth	4.4 m
Average Flow	570 million m^3/year
Total P Load	1,021 t/a (41% from non-point sources)
Total N Load	8,981 t/a
Mean Total P Concentration	0.29 mg/L
Mean Chlorophyll-a Concentration	103 μg/L

Lake Dianchi currently appears to be in the stable state (2) caused by a combination of eutrophication, erosion, loss of littoral area as a result of land reclamation and changed water regime.

Current efforts to control eutrophication of Lake Dianchi focus on the reduction of nutrient loadings from the catchment (Yunnan Institute of Environmental Science 1999). Improved land use practices were implemented for agricultural areas to lower non-point nutrient sources. Major streams in the catchment carrying domestic and agricultural wastewater were equipped with wastewater treatment plants in order to lower point sources of nutrients to the lake. Even though these measures for catchment management were necessary and are the key for preventing future eutrophication of Lake Dianchi, it had little short-term effects in relation to the loading from the current population and agricultural production in the catchment. Over and above that, little has been done so far to restore the natural ecosystem of Lake Dianchi. However, a functioning ecosystem is the prerequisite for turning Lake Dianchi from the current turbid blue-green algae dominated state into a stable clear water macrophyte dominated state.

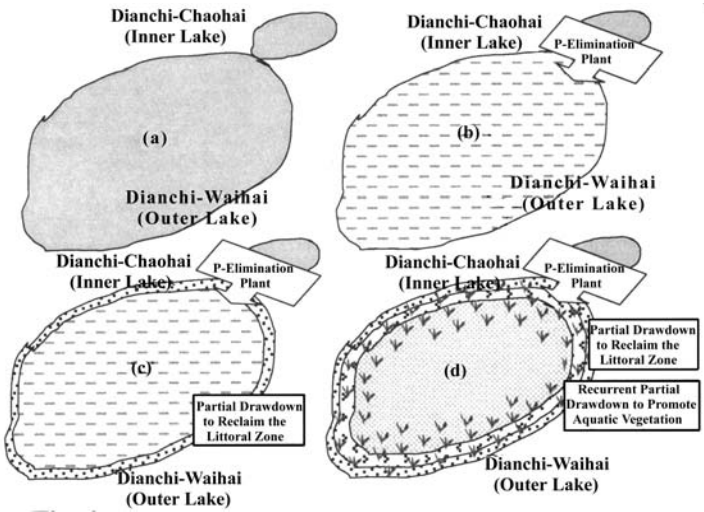

Fig. 10　Prospective restoration management of Lake Dianchi

(a) Highly eutrophic and degraded Lake Dianchi. (b) Control of external nutrient loading to Dianchi-Waihai by implementing a phosphorus elimination plant between Dianchi-Chaohai and Dianchi-Waihai. (c) Reclamation of the littoral of Dianchi-Waihai by permanent partial drawdown. (d) Promotion of aquatic vegetation in Dianchi-Waihai by temporary partial drawdown.

Therefore two additional approaches for the restoration of Lake Dianchi are suggested:

（1）Alteration of the function of the smaller upstream basin Dianchi-Chaohai (Inner Lake) into a pre-dam that collects major point sources of nutrients and is equipped with a phosphorus elimination plant (Bernhardt and Clasen 1990).

The phosphorus elimination plant as designed by Bernhardt and Clasen (1990) is based on flocculation and filtration of nutrients by alum salts. It has been in operation at the Wahnbach Reservoir in Germany since 1978 and removes up to 90% of the soluble reactive phosphorus, 96% of the total phosphorus, and 58% of the dissolved organic carbon from the inflowing water, and lowers chlorophyll-a by 95% in this lake. As this technology proves to be the most efficient and reliable control of external nutrient loading to lakes its implementation at Lake Dianchi would significantly reduce the risk of eutrophication in the major basin Dianchi-Waihai (Outer Lake).

（2）Permanent drawdown of the major basin Dianchi-Waihai (Outer Lake) by 20—40cm to restore its littoral zone, and annual partial drawdown of Dianchi-Waihai by further 20 to 40 cm from November to January. As a result it can be expected that natural germination of higher water plants will be promoted as outlined in Figure 9. In addition it is suggested to plant water plant seedlings in the reclaimed littoral zone. Annual harvesting of recovered water plants needs to be considered as part of this approach in order to prevent nutrient recycling and accumulation in the lake from dead plants. Figure 10 illustrates prospective effects of the consecutive implementation of a phosphorus elimination plant and the permanent or temporary drawdown of Dianchi-Waihai.

4 Conclusions

Research at the Pilby Creek wetland (Australia) has shown the potential of annual temporary drawdown for ecological restoration of shallow lakes. Outcomes of this research have been summarised in a conceptual model that may guide lake restoration by drawdown. The conceptual drawdown model is applied to design a scenario for restoration management of the shallow hypertrophic Lake Dianchi (China). It indicates that drawdown may be the key for the ecological recovery of Lake Dianchi after efficient control of its nutrient loading by a phosphorus elimination plant has been implemented.

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Impacts of Cage Fishery in Lake on Water Eutrophication

Xue Jiyu
Institute of Environmental Sciences, Beijing Normal University, Beijing China

Abstract Lacustrine(reservoir) eutrophication is one of the most serious water environment problems. Wide-spread artificial reservoirs supply water resource for economic and society development. But they have same problems as lake eutrophication. This paper takes Miyun reservoir as study case and its central goal is to analyze the impacts of cage fisher on eutrophication as a interior pollution source. It also analyzes cost-benefit for the water eutrophication and wishes to bring about water resource sustainble use.
Key- words Lacustrine(reservoir) eutrophication Cage fishery

water storage structures composed of vertical water-lock, dam and other constructions. They are built to make use of water resources in flood control, power generation, irrigation, navigation, water supply etc. Usually, they will influence the environment around. According to the statistics from the World Bank, now there are more than 38,000 reservoirs whose water dam are higher than 15 meters. Half of them exist in China, the others are in other countries. Since the foundation of the People 's Republic of China, a great achievement has been made in reservoir construction, which contributes greatly to the country 's social and economic development (see table 1) .

Table 1 The amount of reservoirs built in China

Range	Reservoirs built		Large-scale		medium-diminutive		diminutive	
	amount	capacity	amount	capacity	amount	capacity	Amount	capacity
WholeCountry	84,905	4,517,637	394	32,603,954	2,618	7,242,761	81,893	5,866,922
Beijing	84	931,334	4	880,034	16	43,233	64	6,067

(from《1997 China Water Resource Year Book》)

Though there are many functions of reservoirs, as to a certain reservoir, the importance of each function is different. Ensuring the functions of reservoirs is the central task of reservoir management. Related rules should be made to abide by. Generally speaking, Reservoirs have contribute much to human beings as expected, but there are also some serious problems: water quality is getting worse and worse; eutrophication is becoming more and more extrusive; the problem of siltation is getting serious.

1 Water Quality Problems Faced by Reservoirs

Reservoirs and lakes have a same problem. Under natural conditions, they are both undertaking a gradually change that from oligotrophication to eutrophication. More and more frequent activities of human beings cause various kinds of water quality problems. A great deal of nutrient, such as oxygen-consuming organic matters, nitrogen and phosphorus together with poisonous and harmful substances were discharged to water because of man‘s activities. These substances come into reservoirs though different paths and made the water of reservoirs polluted. Accepted too much nutrient as nitrogen and phosphorus, the alga and other hydrobios will periodically and abnormally increase, so water’ transparency clarity get lower, then, the ecological system and functions of the water are obstructed and damaged, even sea bloom is produced. All these bring great loss of utilization of water resource. Water eutrophication is just a water quality corruption caused by the exotic nutrient and inorganic salts released mineralization of organic matters. Photosynthesis of aquatic plants in eutrophication water may increase the quantity of dissolved oxygen (DO), but when they are discomposed after died, oxygen will be consumed. In 1982 Ulhmann said that 1g of dissolved phosphorus will satisfy the demand of producing 100g alga, while discomposing 100g of alga 150g oxygen is needed.

During the early period of economic development, a large quantity of untreated sewage from living and industry were released. The organic pollution caused by organic matters is a universal phenomenon. With the set-up of sewage disposal plant and the integrity of disposal technique, this kind of pollution could be controlled effectively, but the secondary biochemical treatment technique generally used can not eliminate the nutrient in the water efficiently. Water eutrophication caused by nutrient such as nitrogen and phosphorus that come from interior pollution sources formed by living and industry sewage and non-interior pollution sources formed by agriculture is getting more and more serious.

The water eutrophication of reservoir is a worldwide problem. An inspection made by Kimmel.B and Lind.O in 1990 demonstrates that 85 percents of reservoirs are of mesotrophic, while the percentage of natural lakes is 54.

In china reservoir eutropication is also a serious problem. According to an investigation, the water quality of reservoirs are fine in general, but a good deal of reservoirs near cities or taken as water resources seem likely to be eutrophicated. Based on an investigation on 39 different size of reservoirs, a analysis was made using the method recommended by “investigation standard of lake eutrophication”. The result is illustrated in table 2.

Table 2 Evaluation on Water Eutrophication of Some Reservoirs

	Oligotrophication	mesotrophication	Eutrophication
Amount of reservoirs	10	17	12
Percentage (%)	25.6	43.6	30.8
Capacity (×10)	37.6	546.1	73.94
Percentage (%)	5.7	83.1	11.2

It can be seen that among all the reservoirs investigated, 30.8 percents reservoirs and 11.2 percents of the total capacity are eutrophiced ,74.4 percents of reservoirs and 94.3 percents of the total capacity are mesotrophiced or eutrophiced.

Reservoirs near cities enjoy a high degree of eutrophication. For example, Guanting reservoir of Beijing, Yuquan reservoir of Tianjin and Mogu reservoir of Shizihe are just near eutrophication, which need be taken seriously.

2 Analysis of Eutrophication Trend of Miyun Reservoir

2.1 General situation of Miyun reservoir basin.

Miyun reservoir is one of the most important reservoirs of Beijing. It is also a surface drinking water resource which was built in 1958 and finished in Sep. 1960. Now it is the biggest reservoir of Chaobaihe water system. Its maximum capacity is 4.3 billion m^3 , with a maximum area of 188 km^2. The total area of Miyun reservoir basin is 15,778 km^3, including 9 counties of Beijing and Heibei province. 21.8 percents of its total area which accounts to 3,443.9 km^2 belongs to three counties of Miyun, Huairou, and Yanqing of Beijing. 78.2 percents of the area which accounts to 12,344.1 km^2 belong to 7 counties of Fengning, Guyuan,Chicheng, Luanping,chengde and Xinglong of Heibei province.

Chaobaihe water system is a part of Haihe basin. In this system there are two rivers, the Chaohe and the baihe. The chaohe originates in Fengning county of Hebei province, flows past Fengning, Luanping, comes into Miyun in Gubeikou, enters Miyun reservoir in Gaoling. The total basin area of Chaohe together with its branches is 629.3 km^2. The baihe rises from Guyuan county of Hebei province, flows past Chicheng, yanqing, Huairou, enters Miyun reservoir in Qingshiling of sihetang town, Miyun county. The basin area of Baihe water system is 8575.4 km^2. There are three other rivers, Bmahe, Sheguichuanhe and duijiahe that flow directly into the Miyun reservoir. Miyun reservoir have always take flood control, power generation, irrigation, aquiculture and water supply as main task since built up. From 1980s, the water shortage has been getting serious day-by-day, so the functions of Miyun reservoir have changed greatly. During the period of 1982–1997, the percentage of water used for living increased from 0.2 to 44.6, consumed by agriculture dropped from 85.6 to 19.42, used in environment rose from 0.73 to 8.06. The percentage of water used for industry during 1980 to 1987 rose from 13.72 to 42.25, while in 1988 it begun to drop, in 1991, the percentage is 27.8. The changes point that the function of drinking water supply has been failing gradually.

Table 3 Density of Nitrogen and Phosphorus in Miyun Reservoir of Recent 10 Years

Year		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
TN	Min.	0.370	0.110	—	—	0.021	0.040	0.410	—	0.190	0.390
	Max.	2.100	3.070	0.960	1.763	4.460	2.590	3.600	4.580	2.600	2.610
	Average	0.967	1.041	0.681	0.846	1.127	1.003	2.085	1.557	1.080	1.201
TP	Min.	—	—	—	—	—	—	0.010	—	—	—
	Max.	0.038	0.056	0.058	0.060	0.120	0.056	0.092	0.044	0.212	0.080
	Average	0.013	0.019	0.015	0.008	0.030	0.022	0.021	0.026	0.122	0.029

2.2 Main problems faced by Miyun reservoir

In general, The Miyun reservoir has not been polluted by organic, poisonous and harmful substance. Analyze the measured density of nitrogen and phosphorus in Miyun reservoir of each month in recent 10 years (see table 3) according to the evaluation standard of reservoir eutrophication carried out in 1987 by Hydrologic Department of Hydraulic Ministry, (table 4) it is concluded that based on the average amount of each year, Miyun reservoir is of mesotrophication in most of time, sometimes it is of eutrophication ,and if it is evaluated based on the maximum amount in a year, the reservoir is of mesotrophication to eutrophication, sometimes it is of high europhication.. From all above, we can see that the main problem faced by Miyun reservoir is water eutrophication.

Table 4 Evaluation Standard of Reservoir eutrophication

Status	Oligotrophication	Oligotrophicatio to Mesotrophication	Mesotrophication	Eutrophication
TN (mg/L)	<0.2	0.2－0.4	0.3－0.65	>1.5
TP (mg/L)	<0.005	0.05－0.01	0.01－0.03	0.1

2.3 Analysis of nutrition resource of Miyun reservoir

Generally, the most effective method to control water europhication is to decrease the load of external nutrient source. To do that the first thing is to determine the nutritient load. There are many kinds of nutrient sources, some of which exist within the reservoir basin, some out of the basin. Main external nutrition sources include point source (including the releasing of industry and living sewage) and non-point source (including overland river and atmospheric deposition0. Interior sources include nutrition deposition, cage fishery and under-ground rivers.

Table 5 Amount and Distribution of Nitrogen and Phosphorus Thrown into the Reservoir (of 1 mu)

Percentage (%)	Total amount (kg)	Brought out with fish		Deposit		Enter the water	
		Amount (kg)	Percentage (%)	Amount (kg)	Percentage (%)	Amount (kg)	Percentage (%)
TP	1209	290	24.0	469	38.8	450	37.2
TN	5805	1250	21.5	646	11.1	3909	67.3

The main sources of Miyun reservoir’s nutrient are as follow: nutrient brought to the reservoir by the rivers which are called point resources; nutrient brought by other seasonal branches or coming into the river directly from the bank, which are called non-point resources; cage fishery in the reservoir.

Table 6 The Ratio of Each Month’s Amount of Thrown Bait to the Whole Year’s

May	Jun.	Jul.	Aug.	Sep.	Oct.	Total
10.7	14.39	21.58	21.58	17.39	14.39	100

Table 7　Nitrogen and Phosphorus Load Due to cage Fishery (kg)

Month		May	Jun.	Jul.	Aug.	Sep.	Oct.	A year
Enter the water	TP	910.8	1301.5	1952.7	1952.7	16627.1	1301.5	9046.3
	TN	1911.5	11305.5	16962.2	16962.2	14133.9	11365.5	78580.8
deposit	TP	949.9	1357.5	2036.7	2036.7	1697.1	1357.5	9435.4
	TN	1304.9	1864.7	2797.6	2797.6	2331.1	1864.7	12960.6

Cage fishery in Miyun reservoir begun in 1984. The fishery area then was only 0.5mu, while in 1987 the area increased to 20mu. In 1988 the fishery area grew to 70mu. A large amount of bait is thrown into the water to feed fish, then the water is polluted. Usually, the bait thrown into the water would be transferred and transformed in three ways: taken out with fish; entering the water body; (including the remains of bait, manure and secretion) depositing at the bottom. The total amount of Nitrogen and Phosphorus thrown into the reservoir and their distribution in the water are given in table 5. The bait-thrown period of a year is from May to Oct.. The ratio of each month 's amount of thrown bait to the whole year's are given in table 6 (from May to Oct.) .

Table 8　The Nutrition Load of Miyun Reservoir Coming From Different Sources

Pollution substance	Point source		Non-point source		Cage fishery		Total load (T)
	Load (T)	Percentage(%)	Load (T)	Percentage(%)	Load (T)	Percentage(%)	
NH_3—N	106.18	41.32	150.82	58.68			257.00
$NO_{3.}$—N	1944.95	93.39	137.55	6.61			20.85
NO_2—N	28.92	55.14	23.53	44.86			52.45
DOB_5	1235.46	87.24	180.78	12.76			1416.24
TP	130.69	844.05	15.75	10.13	9.05	5.82	155.49
TN	2080.05	80.57	423.1	16.39	78.58	3.04	2581.74

All the nitrogen and Phosphorus thrown into the water: would be divided in three parts. The first part will be taken out with the fish; the second part that deposits at the bottom of the reservoir is a potential source of nitrogen and phosphorus; the other part that enters water directly is the chief source of nutrient.

Table 9　The Area Load of Nutrient from Different Sources

	Point source	Non-point source	Cage fishery
Area (m^2)	15051.31	736.69	0.013413
NH_3—N	0.007055	0.204727	
$NO_{3.}$—N	0.129221	0.186714	
NO_2—N	0.001921	0.03194	
DOB_5	0.082083	0.245395	
TP	0.008683	0.021375	674.6998
TN	0.138197	0.574339	5858.332

With the actual area of cage fishery and the amount of fish bait thrown in a year, the nitrogen and phosphorus load of each month can be figured out (see table 7).

The nutrient load of Miyun reservoir coming from different sources is shown in table 8.

From the table we know the two rivers of Baihe and Chaohe are the biggest nutrient sources. They provide 80 percents of Miyun reservoir ’s nutrient. So big attention should be paid to the two rivers in controlling pollution source. Furthermore, non-point sources entering the reservoir directly take a quiet big proportion.

Considering the area load of nutrient from different sources (table 9) . we see that the area load of nutrient in the cage fishery area inside the reservoir is bigger than that of outside. So the former should be controlled first. Meanwhile, the area load of nutrient come from non-point sources within the reservoir ’s secondary-protected area is obviously bigger than that from the upper basin.

2.4 Supervision on phytoplankton in cage fishery area of Miyun reservoir

An contrastive investigation made in 1987 between cage fishery area and the non-cage fishery area shows that the amount of alga in cage fishery area is a bit larger than that in non-cage fishery area, while there composition of population is similar. In 1988 the amount of phytoplankton increased distinctly. In cage fishery area the amount of alga is twice of non-cage fishery area. The population composition of sessile and qualitative samples is different between cage fishery area and non-cage fishery area. Some kinds of indicator organism of mesotrophcation such as cyanophyceae, microcystis, gomphonema, chorophyceae, cladophorm and a small quantity of grain melosiro are found in cage fishery area. A small amount of alga among the qualitative samples in non-cage fishery area and zooplankton lived in clear water ,such as Cyclopoids is the main plankton in this area. In cage fishery area this kind of zooplankton can ’t be found.

Miyun reservoir has plentiful sorts of phytoplankton. Before 1983,the chief is diatom. After 1988 the composition of population has changed greatly. The proportion of diatom, pyrrophyta and chrysophyto has decreased , while the proportion of chorophyceae and lanzao has risen. The trend is revealed clearly that the polluted area due to water eutrophication is getting serious year-by-year.

3 Cost-benefit Analysis of Cage Fishery in Miyun Reservoir

3.1 Benefit analysis

According to relative rules, the cage fishery area of Miyun reservoir should be controled within 40mu. Annual net earnings of 1mu is 100 thousand RMB yuan. The total annual earnings of the reservoir is 4,000 thousand RMB yuan.

3.2 Cost analysis

Cage fishery consumes natural resource—water resource of resevoirs. (actually the reservoirs are built as water storage structures to satisfied the need of human beings) The cage fishery cost consists of three parts:

（1）Calculation of exploitation and production cost (C_1): It includes cost of device, fry, manpower, transportation and forage. Gross product of cage fishery abstracting the total income is the cost. According to market investigation, the price of fish is 9.0 RMB yuan/kg. The output is 33,000kg/mu. The gross product is 10908 thousand RMB yuan. Annual exploitation and production cost of cage fishery is: C_1=gross product-total income, that is ,

$$C_1=10{,}908-4{,}000=6{,}908 \text{ (thousand RMB yuan)}$$

（2）Calculation of external and environmental cost (C_2): The main function of Miyun reservoir is providing drinking water for Beijing. The external and environmental impact made by cage fishery is the quality decline of water supplied. Cage fishery is one of the nitrogen and phosphorus sources of Miyun reservoir. Once water eutrophication takes place, relative measures such as throwing a definite deal of flocculating agent or introducing “bio-expanded clay pre-treatment technology” must be taken by water works to clean the water. The cost of one-time consumption, together with the added cost of attendance forms the cage fishery’s external and environmental cost. There are two waterworks taking Miyun reservoir as water source. Their day-supply capability is 1,200 kt. To introduce “bio-expanded clay pre-treatment technology”, in the light of the one-time consumption is 214.5 RMB yuan/t, the total investment is 250,965 thousand RMB yuan. If the life span of the processor device is 50 years, the annual processor cost is 5,019 thousand RMB yuan. Supposing the added cost of attendance is 0.019 RMB yuan/t, the annual added cost of attendance is 81,114 thousand RMB yuan. So the external and environmental cost of cage fishery (C_2) can be figured out:

$$C_2=(5{,}019+8{,}114)\times 32.1\%=4{,}216 \text{ (thousand RMB yuan)}$$

“32.1” is the factor regarding to cage fisher’s contribution to water eutrophication.

（3）Cost of consuming resource (C_3): The water pollution in a definite area caused by cage fishery is a form of natural consumption. Considering the current cage fishery area, the quality of the water within the whole area of 40 mu has gone beyond the standard of drinking water. The cage fishery area multiply water depth and a influence coefficient K=3,(it is supposed that the polluted volume is three times of cage fishery volume) gains the total quantity of polluted water Q:

$$Q=\text{K}\times 40\text{mu}\times 40\text{ m}=3\times 28{,}000\text{m}^2\times 40\text{ m}=3{,}360{,}000\text{m}^2$$

For the time being, the reasonable price is 3 RMB yuan/m^3. (provided by Hydraulic Bureau of Beijing). Replacing the quantity of polluted water calculated above with tap water and considering the coefficient indicating the influence on water quality made by cage fishery which is 32.1%, cost of natural resource consumption C_3 is:

$$C_3=Q\times 3\text{ RMB yuan/m}^3\times 32.1\%=3{,}236\text{ thousand RMB yuan.}$$

Based on the three parts of cost calculated above, the annual cost of cage fishery should be:

$$C=C_1+C_2+C_3=6{,}908+4{,}216+3{,}236=14{,}360 \text{ (thousand RMB yuan)}$$

The total cost of cage fishery is three tmes of the gross product. In the total cost of 14,360 thousand RMB yuan, 6,908 thousand RMB yuan is paid by the stockman, the surplus are paid by water consumer. The loss caused by cage fishery is compensated by the government or transferred to the citizen's load. On the view of environmental economics cage fishery is infeasible.

In summery, the decline of water quality caused by cage fishery will destroy the ecological balance of the reservoir and the around area, meanwhile, make a long-term , potential bad impact on the sustainable development of environment and economic. Considering benefit of the whole society cage fishery costs more and gains less.

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Successful Eutrophication Management In Lake Balaton, Hungary–Methods, Expectations, Surprises, And Recommendations

Vera Istvanovics

Water Resources Research Group of the Hungarian Academy of Sciences

H-1111 Budapest, Mûegyetem rkp. 3. Hungary

Abstract This paper presents the story of successful eutrophication management in large, shallow Lake Balaton from both scientific and technical aspects. Features that are worth following or that should be avoided in the case of other lakes are emphasized. Rapid eutrophication has been observed in the western areas of the lake during the 1970s. Eutrophication caused a considerable loss to tourist trade, and seriously endangered ecological values of the lake. A comprehensive water quality management plan has been approved in the early 1980s. Merits and drawbacks of this plan are discussed. Management of nutrient loads point (sewage diversion, P precipitation in large sewage treatment plants) and non-point sources decreased loads by 45%–50% to a mean 159 T Pa^{-1} in the period 1988–1998. This relatively moderate reduction in the P load resulted in a surprisingly fast recovery of Lake Balaton, most likely due to the rapid immobilization of the mobile sedimentary P. Success of water quality management in Lake Balaton should shift the focus from immediate actions towards prevention.

Key-words Shallow lakes Point sources Non-point sources Long-term behavior of sediments Cyanobacteria Planning Implementation Monitoring Recovery

1 Objectives

The aim of this paper is to briefly overview water quality management in Hungary and to present the experience of eutrophication management in the largest Hungarian lake, Lake Balaton in both scientific and managerial terms. Features that are worth following or that should be avoided in the case of other lakes are emphasized.

2 Water quality management in Hungary–an overview

Hungary is a country of numerous extremely small and shallow lakes and ponds, more than half of which are artificial ones (fishponds, lowland reservoirs constructed for irrigation, oxbows, etc.). They comprise less than 0.1% of Hungary's water resources and cover less then 2% of the country (Fig. 1). Most of them can also be classified as wetlands; these systems are protected. Although shallow ponds are extremely sensitive to pollutants, they experience a disproportionately high human impact relative to less sensitive Hungarian rivers. The reason is twofold. First, the majority of our ponds are situated in intensely cultivated agricultural areas and thus, they are

Fig. 1　Lakes in Hungary

subject to high diffuse loads. Second, the demand for water bodies that can be used for recreation, fishery and angling considerably exceeds the capacity of lakes and ponds of suitable water quality. The consequence is that our standing waters suffer various water quality problems, most often eutrophication. According to the OECD (1982) classification, 27% of the regularly monitored Hungarian lakes (N=77) are mesotrophic, 34% are eutrophic, and 39% are hypertrophic. Stratified ponds that developed in abandoned sand, stone, clay, etc. mines tend to have the best water quality. Lowland reservoirs and fishponds are typically hypertrophic. The three largest lakes including Lake Balaton (Fig. 1) contribute by two thirds to the total lake surface area and volume. The latter are internationally and/or nationally recognized recreational lakes, whereas the remaining lakes and ponds are of local or regional importance.

Water quality management faces a series of specific problems in Hungary.

（1）Long-term behavior of the sediments is a key factor in determining the trophic response of lakes, and particularly those of shallow ones. Although this fact is widely recognized (Sas 1989), we do not possess appropriate methods for evaluating this vital aspect of eutrophication management. Promising approaches have been developed in the case of Lake Balaton (see below).

（2）Nutrient loads of acceptable accuracy cannot be derived directly from the limited number of available water quality data. The share of diffuse and point loads can neither be estimated easily. Several mathematical-statistical methods have been developed to refine annual nutrient loads at various scales (Clement & Buzás 1999).

（3）Several conflicting water usages (recreation and fishery, recreation and nature protection, fishery and nature protection, irrigation and angling, etc.) characterize most of Hungarian lakes and ponds. In the case of small, locally important water bodies it is typically very difficult to arrive at a compromise concerning priorities of water usage. When morphometric properties and in-lake processes allow, different priorities can be defined for various areas of the lake. The latter approach has been applied with success in a number of Hungarian lakes.

（4）Economic situation of the country does not allow application of costly management measures typical in developed countries. Maximizing the efficiency of low-cost methods stresses the importance of exploiting each possibility that specific features of the lake or its surroundings provide. Instead of ambitious large steps we must relay on several affordable small ones to achieve an acceptable level of water quality.

Lake Balaton is an outstanding example of successful eutrophication management both in national and international terms. One can hardly find a similarly shallow and large lake in which reduction of nutrient loads led to such a rapid and significant water quality improvement as in Lake Balaton (cf. Sas 1989). The rest of this paper presents information about eutrophication management of Lake Balaton.

Table 1 General physical Characteristics of lake Balaton and the kis-balaton pre-reservoirs
(Exchange time, t_{ex} was estimated as the volume divided by inflow+throughflow for the basins of Lake Balaton)

	V	Z_{mean}	Surface area (km^2)		Areal ratio catchm.	t month	t_{ex}
	10^6 m^3	m	"lake"	catchment	/lake		
Basin 1	82	2.3	38	2750	72	3	–
Basin 2	413	2.9	144	1647	11	39	12
Basin 3	600	3.2	186	534	3	199	18
Basin 4	802	3.7	228	249	1	1003	26
Balaton	1897	3.2	596	5180	9	47	47
Upper Reservoir	21	1.1	18	1779	99	1	–
Lower Reservoir	64	1.2	51	722	14	4	–

3 Lake Balaton and its Eutrophication

Lake Balaton is a large, shallow lake that can be divided into four consecutive basins (Table 1, Fig. 2). The largest tributary, the Zala River (mean flow at the mouth is 7.8 m^3 s^{-1}) drains nearly half of the catchment of the lake into the smallest Basin 1. The only outflow is the Sió Canal that connects Basin 4 with the Danube (Table 1, Fig. 2).

Major socio-economic development took place around the lake and in its catchment after World War II (Somlyódy & van Straten, 1986). About half of the catchment became cultivated. Of the cultivated area, arable land made up 60%. Poor, acidic soils are susceptible to high soil erosion particularly in the north-western catchment, including the Zala River watershed. The annual average rate of erosion varies between 4–6 thousand t km^{-2}. Between 1950–1975, fertilizer use increased by a factor of 60. Due to overfertilization, 440 kg hm^{-2} of P has accumulated in the topsoil during the period 1965–1985 (Sisák 1993). More than 40 industrialized animal farms were built. Tourist trade rose by a factor of 14, and the number of permanent inhabitants doubled. Sewerage construction started in the mid-1950s, but only 15% of the utilized water received secondary treatment in 1975. From the late 1960s, P-based detergents have been applied increasingly.

By the 1980s, direct sewage load made up 25% of the biologically available P (BAP) load to the whole lake (Table 2, Clement *et al*. 2000). Direct sewage accounted for a major part of BAP load in Basins 3 (40%) and 4 (70%) that have small subcatchments and high exposure to tourism. Tributaries discharged more than 75% of the BAP load to Basins 1 and 2. The Zala River alone transported 20% of the BAP load of the whole lake. Sixty percent of the total P (TP) load (51 t a^{-1})

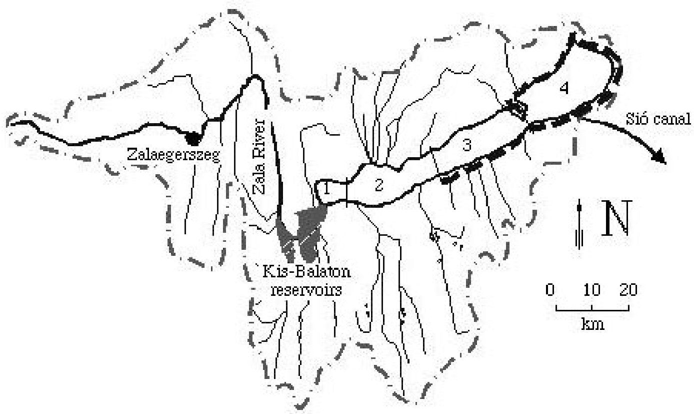

Fig. 2 Lake Balaton and its watershed area
Numbers indicate the four basins. Dashed line shows sewage diversion from the shoreline settlements.

of the river originated from point sources. The largest town in the catchment, Zalaegerszeg (60 thousand inhabitants; Fig. 2), emitted 36 tons P a^{-1}. Of this, 70% was estimated to reach the lake (Somlyódy & Jolánkai 1986).

Table 2 Average loads of total and biologically available P (TP and BAP, respectively) of Lake Balaton before (1980–1987) and after (1988–1998) load reduction in tons P a^{-1} (Clement et al. 2000)

Load component		Whole lake	Basin 1	Basin 2	Basin 3	Basin 4
In the period 1980–1987						
Tributaries	TP	190±50	97±5	65±21	25±12	13±12
	BAP	117±20	58±1	38± 9	13± 5	8±5
Direct sewage	TP=BAP	24±5	0± 0	1± 0	9± 2	14± 3
Direct runoff	TP	42±26	6±4	5± 3	13±8	18± 8
	BAP	12±7	2±1	1± 1	4± 2	5± 3
Atmospheric	TP (BAP?)	17±7	1±0	4± 2	5± 2	7± 2
Total load	TP	284±88	104±9	75±26	52±24	52±29
	BAP	152±32	60±2	40±10	26± 9	27±11
In the period 1988–1998						
Tributaries	TP	85±20	45±0	31±14	8± 5	1± 0
	BAP	48±7	26±0	14± 8	4± 1	1± 0
Direct sewage	TP=BAP	24±5	0±0	3± 1	1± 0	0± 0
Direct runoff	TP	37±23	6±4	5± 3	11± 7	15± 9
	BAP	11±7	2±1	1± 1	3± 2	5± 3
Atmospheric	TP (BAP?)	20±9	1±1	5± 2	± 3	8± 3
Total load	TP	159±60	54±6	51±23	28±17	26±14
	BAP	68±18	29±2	23± 8	9± 4	7± 4

Increased nutrient loads induced rapid eutrophication in Lake Balaton during the 1970s (Fig. 3, Herodek 1986). Summer blooms of heterocystic, occasionally toxic cyanobacteria (*Aphanizomenon flos-aquae, Anabaena spiroides, Cylindrospermopsis raciborskii*) occurred regularly in Basin 1. *C. raciborskii* invaded the whole lake during hot summers (Padisák, 1994). According to the OECD (1982) classification, the southwestern basins became hypertrophic. Although the northeastern basins remained mesotrophic, their water quality also deteriorated (Fig. 3).

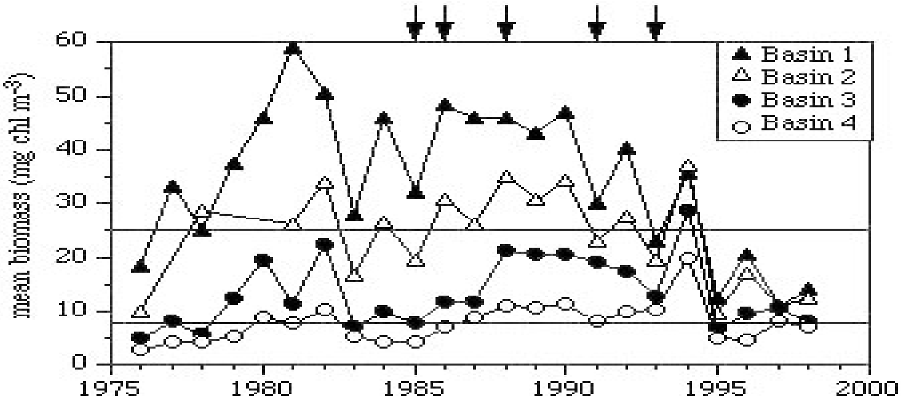

Fig.3 Long-term variation in the algal biomass in four basins of Lake Balaton

(Arrows indicate the timing of main management measures: opening the Upper Kis-Balaton reservoir, sewage diversion from Basins 3 and 4, cessation of the bauxite mining, P precipitation at the sewage treatment plant of Zalaegerszeg, partial inundation of the Lower Kis-Balaton reservoir, cf. Fig. 2. Horizontal lines indicate the boundaries of meso-, eu-, and hypertrophic levels according to the OECD (1982) classification).

Eutrophication led to manifold ecological and economic losses. Lake Balaton is an internationally recognized recreational lake that attracted over 2 million tourists each summer during the 1980s. Yearly income from tourism represented one thirds of Hungary's total tourist income. Commercial fishery (1,200 t a^{-1}) and angling are important in Lake Balaton, but increased productivity has shifted the composition of the fish fauna towards less valuable species (e.g. bream, Bíró 1984). Cyanobacterial blooms, repeated fish kills, retreat of the shoreline reed stands, mass emergence of chironomids were side-effects of eutrophication that stirred up the public and urged large-scale management measures.

4 Management Measures And Recovery Of Lake Balaton

Up to now, P load of Lake Balaton has been reduced by 40%–50% (Table 2). Point sources were controlled by (1) closing up large-scale animal farms, (2) sewage diversion from the shoreline settlements of the northeastern basins by 1986, and (3) introduction of P precipitation at the largest sewage treatment plants of the catchment with an effluent standard of 1.8 mg P m^{-3} (1985–1991). In order to manage non-point sources, the Kis-Balaton pre-reservoirs were constructed in a former wetland area near the mouth of the Zala River (Fig. 2; Table 1). The Upper Reservoir was inundated in 1985, whereas the Lower Reservoir has not been fully implemented yet.

Although Lake Balaton possesses each unpleasant feature that potentially hinder eutrophication management - large, shallow lake with a long history of eutrophication, high share of non-point loads, presence of bloom-forming cyanobacteria - a relatively mild decrease in the P load (Table 2) led to an unexpectedly large improvement in the water quality of its Basin 1 (Fig. 3). Besides the decrease in the annual biomass of algae, gradual recovery of the former mesotrophic phytoplankton, zooplankton, and zoobenthos communities has been observed during the last few years.

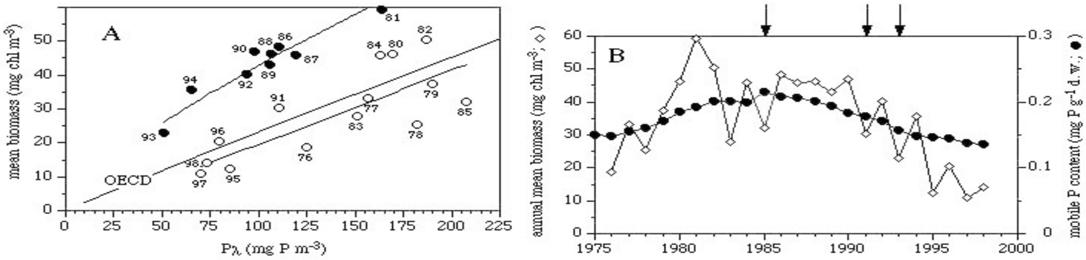

Fig. 4 Mean algal biomass as a function of the inlake P concentration calculated according to the OECD (1982) model (A) and that of the estimated mobile P content of the surface sediments(B) in Basin 1 of Lake Balaton

(Inside A numbers indicate years. Regressions - open symbols: chl = 0.13 Pl1.09, r2=0.72, n=14; closed symbols: chl = 1.41 Pl0.74, r2=0.90, n=9. In B arrows show the timing of main management measures: opening the Upper Kis-Balaton reservoir, P precipitation at the sewage treatment plant of Zalaegerszeg, partial inundation of the Lower Kis-Balaton reservoir, cf. Fig. 2.).

The relationship between the external P load and mean algal biomass conformed to the OECD (1982) model in many years. However, in most years immediately after the reduction in load (1986–1994), as well as in the years of *C. raciborskii* blooms, the same external load supported by about 20 mg chl m^{-3} higher algal biomass than in other years (Fig. 4A). The conclusion is that internal P load has been high in the latter years, and long-term behavior of sediments is a key factor in determining the success of nutrient management in lakes (Sas 1989, Somlyódy 1998, Istvánovics & Somlyódy 1999, in press). Accordingly, long-term changes in algal biomass were more closely related to long-term changes in the mobile P content of the sediments than to the momentary external P load (Fig. 4; concentration of mobile P was estimated from mass balance of the surface sediments. For details see Istvánovics & Somlyódy, in press). Fast immobilization of the mobile P pool in the highly calcareous sediments of Lake Balaton (carbonates make up 50%–60% of dry mass; Máté 1987) might be the principal factor that led to the unexpectedly fast recovery in Basin 1.

The other three basins of the lake were subject to a similar relative reduction in their external P loads as Basin 1 (Table 2). Surprisingly, a definite eutrophication followed the reduction in the nutrient loads in the mesotrophic Basins 3 and 4 (Fig. 3). Enhanced internal P load did not account for this paradoxical phenomenon. The most likely reason was the substantial decrease in the hydraulic load of these basins as a consequence of natural processes and first of all, human intervention. The latter included cessation of bauxite mining and associated pumping of karstic water into surface flows. This clearly stresses the importance of widening the traditional scope of eutrophication management (Istvánovics *et al*., in prep.).

5 Analysis of Various Management Measures

Due to its cost-effectiveness, reduction in nutrient loads from point sources is typically the first step in eutrophication management. Thus, the share of much less easily controllable non-point sources tends to increase in time. Sewage diversion and P precipitation at the largest sewage treatment plants decreased the annual mean BAP load to Lake Balaton by 40–50 t P a^{-1}. One third of the present total P load of 160 t P a^{-1} (Table 2) may still originate from point sources. If water quality of the lake had not improved as much as presented above, lowering the effluent standard from 1.8 mg P m^{-3} to 0.5 mg P m^{-3} would be of high priority. The experienced improvement, however, should shift the focus of eutrophication management towards controlling diffuse nutrient loads whereas gradual reduction of point sources can proceed slower. A considerable portion of the non-point loads originates from agriculture.

The concept of the Kis-Balaton Reservoirs as a tool for reducing diffuse loads was put forward during the 1980 s (Somlyódy & van Straten 1986), when agriculture was considered to be the leading sector of Hungarian economy. Political will of maximizing agricultural production rendered water quality protection an important, albeit secondary question. Under these circumstances, construction of the pre-reservoir was the only feasible solution for managing diffuse nutrient loads from agriculture.

The inundated part of the planned reservoirs comprises the Upper Reservoir, which is a hypertrophic pond, and the Ingói area, which is a reed dominated wetland (Fig. 2, Table 1). In the Upper Reservoir, retention efficiency of total P reached 50% after its inundation in 1985. Due to the increased internal P load, retention efficiency dropped to 20% in 1991 when P precipitation at the sewage treatment plant of Zalaegerszeg reduced the external P load to the reservoir from 4.9 to 2.4 P m^{-2} a^{-1} (Istvánovics & Somlyódy 1999). P retention in the Upper Reservoir could be predicted with a considerable degree of confidence. The key to successful prediction was the assessment of the long-term behavior of sediments (Somlyódy 1998, Istvánovics and Somlyódy 1998). Operation of the Upper Reservoir arose several questions about positioning and dimensioning pre-reservoirs that should be considered when similar measures are taken elsewhere.

In contrast to the Upper Reservoir, retention efficiency of nutrients was poorly predictable in the Ingói area in the lack of general relationships concerning nutrient retention in wetlands (Somlyódy *et al*. 1997). Our experience showed that retention efficiency was dependent on the hydraulic regime, on the type of the vegetation, as well as on the type and chemical species of nutrients. In addition to this, a serious and not yet resolved conflict arose between nature protection and water quality management about the future of the Lower Reservoir. At the present time, it does not seem advisable to relay on large natural wetlands for retaining nutrient loads from lakes in which algal biomass is P-determined. In rivers and inland seas, where the prime objective is to minimize the loads of nitrogen, wetlands represent an efficient management option (Mitsh & Gosselinck 1986).

After major political changes in Hungary in 1989, the concept of agricultural development was radically revised. Instead of quantitative production, quality, efficiency, economy and environmental protection became prime issues. Now Hungary is a candidate for the membership of the European Community. Our agriculture is to be reorganized in accordance with the priorities of the EC's agricultural policy that focuses on managing agricultural production in a sustainable way with special reference to protection of both soils and waters. The transition to the new agricultural policy is in progress. Undesirable and chaotic features often characterize the process. Thus, privatization has drastically decreased the size of farming units to a mean of only 1–2 hm^2, that is far beyond the limits of the contemporary agrotechnical means. Sudden withdrawal of previously high state subsidy from mineral fertilizers dropped the rate of fertilizer application by 70%–75%, that is to levels that would not maintain the former yield in a long run. These factors, along with the poor predictability of the outcome of the agricultural transition make extremely complicated to elaborate and implement comprehensive measures for managing diffuse loads. Fertilizer management, erosion control, appropriate legal regulation, support on environmentally friendly procedures, improved technology transfer, public awareness, interdisciplinary research are the most important prerequisites to minimize P losses from the watershed.

Considering the temporal, legislative, financial, and organizational needs of diminishing agricultural emission of nutrients, a major benefit of pre-reservoirs is that they allow time to introduce various measures capable of reducing diffuse load emission from the agriculture, as well as to test environmental and socio-economic impacts of these measures. After minimizing the loss of P from the watershed, pre-reservoirs are expected to polish uncontrollable loads of nutrients. Conclusively, construction of pre-reservoirs does not replace but efficiently supplements comprehensive measures taken to reduce P transfer from terrestrial to aquatic environments.

Various in-lake measures are often needed to speed up recovery of lakes after appropriate reduction in their external loads. The single in-lake measure considered to be feasible in large Lake Balaton was sucksion dredging. In order to reduce internal P load, the nutrient-rich surface sediment layer (15–20 cm) should have been removed from an area of 20 km^2 in Basin 1. Intense monitoring and modeling results, however, have questioned recently the efficiency of this measure (Papp 2000). Due to wind-induced sediment resuspension followed by sedimentation, freshly exposed sediments contained detectably less mobile P and released less P than the original ones only for a few weeks. More importantly, favorable long-term behavior of the calcareous sediments of Lake Balaton (see above) makes expensive dredging needless.

6 Retrospective Evaluation of Eutrophication Management in Lake Balaton

The plan of eutrophication management for Lake Balaton had been elaborated during the early 1980s and approved by the Council of Ministers in 1983. The plan defined short-, medium-, and long-term water quality targets, as well as permissible nutrient loads for each basin of the lake. Various measures to be taken for reducing nutrient loads were also specified, scheduled (Table 3) and budgeted. Water quality improvement achieved so far in Lake Balaton is indicative of the overall success of the process of eutrophication management from planning through decision making to implementation and monitoring. Generalization of the approach, however, requires a closer insight into details that so often determine the whole. The aim of the forthcoming discussion is to explore main merits and drawbacks of the management process followed in the case of Lake Balaton.

Table 3 The plan of eutrophication management in Lake Balaton

Level	Schedule	Target qualitative	Load reduction%	Basin	Target mg chl m^{-3}	Load tons $BAPa^{-1}$	Main measures
Level A	1990	further water quality deterioration prevented	20	Basin 1 Basin 2 Basin 3 Basin 4			P precipitation at large sewage treatment plants by1985; Kis-Balaton reservoirs and sewage diversion by 1987; sewarage construction in shoreline settlements
Level B	1995—2000	significant water quality improvement	80	Basin 1 Basin 2 Basin 3 Basin 4			sediment dredging; managing diffuse loads
Level C	2005—2010	water quality experienced during the 1960ies	90	Basin 1 Basin 2 Basin 3 Basin 4	20 12 6 4	6 15 7 5	managing diffuse loads

6.1 Merits

（1）*Scientific background*. Nowadays it is widely recognized that appropriate information on both nutrient loads and in-lake ecological processes is a prerequisite for planning a sound eutrophication management strategy and lowering the often expensive risk of failure. The situation was exceptionally favorable in the case of Lake Balaton where limnological research dated back to the late 1920s, and regular water quality monitoring started both in the lake and its larger tributaries in the mid 1970s. Moreover, Lake Balaton was chosen as a case study for modeling and managing shallow lake eutrophication–a project performed by the International Institute for Applied System Analysis (IIASA) in cooperation with the Hungarian Academy of Sciences and the National Water Authority between 1978–1982 (Somlyódy & van Straten 1986).

（2）*Priorities*. Lake Balaton was defined as a recreational lake and water quality targets were set up accordingly.

（3）*Realistic water quality targets* - *appropriate measures for reducing loads*. Both of these requirements depend on background information available for planning. Selection of the most appropriate measures was and should be based on several criteria including cost-efficiency, social criteria, specific hydrogeographical conditions, etc.

（4）*Uncertainties recognized.* One of the most important objectives of modeling was to analyze uncertainties caused by stochastic fluctuations of hydrometeorological and loading conditions, unpredictable features of ecosystem development, and insufficient knowledge of several decisive limnological processes (Somlyódy & van Straten 1986). Various management options were evaluated on the basis of their influence on the expected uncertainty of water quality improvement. Reduction of point sources, for example, was more cost-effective than managing diffuse loads by pre-reservoirs. Unlike, however, the former option, the latter measure also decreased variability of the external loads and consequently, reduced year-to-year variation of the expected algal biomass (Somlyódy & van Straten 1986).

（5）*Flexibility*. Handling of uncertainties makes flexibility of the management process vitally important. In the case of Lake Balaton, the government decision in 1983 prescribed comprehensive evaluation of the progress both in terms of water quality improvement and nutrient load reduction every five years. If needed, water quality targets and permissible loads must be updated. Monitoring data and scientific progress are the inputs of regular supervisions performed by an independent organization that is a temporary committee organized by the Hungarian Academy of Sciences. Responsible ministries delegate their representatives into the committee.

6.2 Drawbacks

（1）*Institutional problems*. In spite of the nation-wide importance of water quality management of Lake Balaton, a specific Balaton low has not been approved, a specific authority or co-ordinative organization has not been appointed. At the present time, seven ministries are nominated as the execution bodies of Lake Balaton action program. Three of them are directly related to the environmental protection of the lake through their local agencies. Of the latter, Lake Balaton belongs to three Inspectorates for Environmental Protection (IEP, Ministry of Environmental Protection) and three Water Authorities (WA, Ministry of Transportation and Water Management). Administratively, three different counties share the lake. In addition to this, municipal governments and several other organizations (e.g. Balaton Development Council, Transdanubian Regional Waterworks Incorporation, NGOs) have various tasks and responsibilities concerning environmental protection of the lake.

The confusing institutional system and the lack of a single responsible “owner” led to a series of problems during the implementation of the action program and in continuous assessing of the progress. Two examples illustrate these problems. First, introduction of P precipitation at the sewage treatment plant of Zalaegerszeg has been scheduled before implementation of the Kis-Balaton pre-reservoirs (Fig. 2; Table 3). Deficiencies of the regulations, however, allowed incorrect allocation of the available budget and premature implementation of the Upper Reservoir (Istvánovics 1991). Due to the incorrect sequence of implementation, the reservoir operated much below its phosphorus retention capacity after 1991 (see above). Second, the lack of a central database make data availability very poor, greatly reducing the efficiency of the otherwise carefully planed monitoring system. The three IEPs are responsible for water quality measurements in both the lake and its inflows, whereas the three WAs register flows. The two databases are fully separated. Collection and processing of statistical data (e.g. number of inhabitants, fertilizer application, landuse, etc.) are organized exclusively on the basis of administrative units.

（2）*High inertia*. Although the principle of flexibility has been built into the management plan, it was difficult to realize flexibility in practice for two main reasons. First, a sufficiently long time period (10–15 years in the case of Lake Balaton) passes before water quality improvement can be identified with confidence due to stochastic variability of the environmental conditions and associated variability of algal biomass. Second, re-allocation of the budget is not easy due to the resistance of contra-interested institutions.

7 Conclusion and Recommendations

The case of Lake Balaton indicates that large, shallow lakes with a long history of eutrophication and high share of diffuse nutrient loads can be managed successfully. There are several keys to success. From a scientific point of view, one may emphasize (1) the need for properly assessing long-term behavior of the sediments, (2) careful analysis of the uncertainties, and (3) developing methods to estimate nutrient loads with sufficient accuracy from scarce water quality data. From a managerial point of view, (1) compromising the conflicting interests of various water usages, (2) flexibility of the management plan, and (3) thorough development of the institutional background are the most important prerequisites.

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The Eutrophication of Major Lakes and Remedial Measures in Korea

Deok-Gil Rhee Hae-Kyung Park

Water Quality Research Department, National Institute of Environmental Research, Korea

Abstract Eutrophication and algal-bloom is one of the key environmental issues in Korea. Though it was precautionary level, there have been algal blooms in several lakes in Spring and Summer season. Lakes in Korea are susceptible to eutrophication because of large catchment area, long retention time and hydrological and meteorological conditions. Preventive measures against the eutrophication include construction and expansion of environmental facilities to treat domestic sewage, industrial wastewater, livestock wastewater, restriction on location of pollutant emitting facilities, establishment of reparian buffer zone along the lake and riverside which used as drinking water sources, introduction of nutrient removal techniques, etc. Because there is no single solution to the eutrophication, it is important to carry out interdisciplinary research on eutrophication and development of technologies to prevent and remove eutrophication. We wish to share information and experiences with neighbouring countries who has similar problem and tasks, so that the water quality in this Northeast Asian region can be improved effectively to meet people's needs in this region.

Key-words Lake eutrophication Reparian buffer zone Preventive measures

1 Introduction

The Republic of Korea occupies a total land area of 99.3×10^9km^2 at the Korean peninsula between Chinese continent and Japanese archipelago in North-east Asia. Since 47 million Korean people make livelihood in that land area, the nation is one of the most densely populated in the world; per capita land area is 2,300m^2.

Korea has achieved remarkable economic development and per capita income during last three decades, but urbanization, extensive landuse and massive industrial production has brought about serious environmental problems such as air and water pollution, solid waste disposal, etc.

The water resources are also limited. The total volume of annual water resources coming from the precipitation is 126.7×10^9m^3. 55% of this total is the surface runoff and 45% is lost in the form of evaporation and infiltration. In 1998, out of 126.7×10^9m^3, stream water is 17.2×10^9m^3 or 14% of total resources. This indicates that only 22% of the total water resources are presently utilized. Such a low rate use can be explained by the fact that two-thirds of precipitation is concentrated in the period from July to September, the summer season, and hence most of it is lost as flood water.

It is in this reason that we have constructed more than 18 thousand dams and reservoirs which catch and keep the rainwater in rainy season for use in dry season of the year. Dam water is $10.3 \times 10^9 m^3$ or 8 % of the total resources. Most of dams and reservoirs in Korea are used for drinking water sources. Because of this, it is becoming important to protect and improve water quality of major lakes through national plans and programs.

2 Present Conditions of the Eutrophication in Korea

2.1 Factors mustering the eutrophication

The causes of eutrophication are closely linked with hydrological characteristics of the lakes susceptible to algal blooming. Most of lakes in Korea are man-made, artificial reservoirs and we have very few natural lakes. Because of this, Korea's lakes are characterized by large catchment area per water surface, and large amount of inflow of nutrient into the lakes has great potential for eutrophication. Another point is that Korean lakes are elongated, stream-shaped and because of this it is sometimes difficult to apply water quality prediction models developed in other countries.

Secondly, steady growth in population and industrial facilities together with urbanization in the basin inevitably caused increased pollution loads. Non-point pollution such as agricultural runoff, aqua-culture, various development activities such as construction of housing, roads, resort facilities, etc. also contribute to the growing environmental distress.

Thirdly, insufficient wastewater treatment facilities in number and capacity, particularly upsteam of lakes, is major problem in combating eutrophication. Though there is legally binding instrument to control livestock wastewater, there are still many small scale livestock farms which are not legally under control. Pollution loads of livestock wastes and fertilizer account for 80.6% of nitrogen and 86.7% of phosphorus.

2.2 Current status of eutrophication and algal growth in Korean lakes

Korean lakes can be divided into two types according to their hydraulic properties, that is river-type lakes and lake-type lakes. In the lake-type lakes which are large and have long retention time, dam gate is closed for the flood control of downstream and there is large amount of nutrient loadings from the catchment during the high rainfall period of summer and subsequent algal blooms appear right after the rainy season. In contrast, in the small river-type lakes of downstream, shorter retention time and high turbidity inhibit the algal growth during the rainy season(table 1).

Table 1　Pattern of algal growth by lake type in Korea

Categories	Lake-type Lakes	River-type lakes
Retention time of nutrient	Long	Short
Period of stratification	June～October	no stratification
Fate of nutrient after Rainy season	Intake by algae	Washed out
Period of algal blooms and dominant species	After the heavy rainfall in summer, cyanobacteria	• drought period in spring and autumn, diatoms • drought period in summer, cyanobacteria
Algal growth pattern During the stratification Period	massive growth (due to the high nutrient loading, stratification, long retention time)	low growth (due to the high turbidity, short retention time)

Korea has distinctive four seasons. Lake environment changes markedly with the season. Heavy rain during July-August carries nutrients into the lake and creates good environment for algae to grow massively in summer or early autumn.

Monthly patterns of chlorophyll a concentration are quite variable(Fig. 1). The first significant increase of chlorophyll-a occurs in the spring when the diatom species blooms. The second chlorophyll peak occurs in the summer(from July to September) which is associated with cyanobacterial blooms. May, June and winter season are characterized by low chlorophyll a concentration. Seasonal succession of dominant species occurs in all river system. Diatoms dominate in winter and spring, green algae and cyanobacteria follow in summer and early autumn and diatoms recur in late autumn.

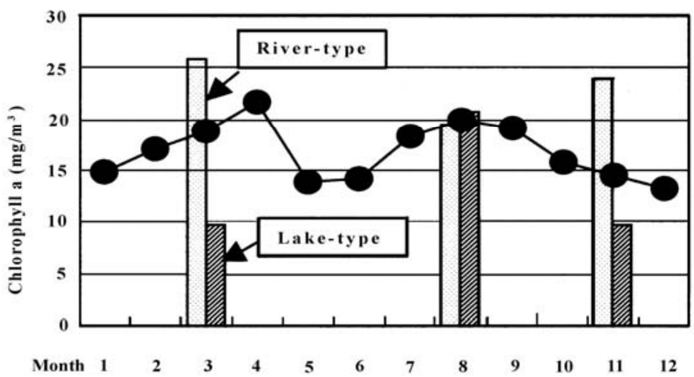

Fig 1.　Monthly variation of chlorophylla concentration in Korean lakes

3　Remedial Measures against the Eutrophication

3.1　Basic Policies for Water Quality Improvement of Four Major Rivers

The four main rivers—the Han, the Nakdong, the Youngsan and the Keum rivers are the basis of life in Korea and the main sources of drinking water. Despite various regulatory measures, continued supervision and guidance, and expansion of basic environmental facilities, the water quality of four main river system has continued to decline due to increasing numbers of pollution sources which are too small to be regulated by law, and to the acceleration of development in semi-agricultural and forest areas since restrictions on development were lifted under the revised National Land Use and Management Act in 1994.

Korea's water quality management policy has therefore placed top priority on protecting water resources that provide people with safe drinking water. Beyond that, the policy involves the protection of river quality; in essence, all riverine ecosystems should be sustainable managed to maintain a high level of ecological health and aesthetic integrity. For this purpose, the government has developed water quality standards, detailed plans and laws, and has increased its investments in water quality improvement measures.

Household sewage is controlled by the Sewage, Night Soil and Livestock Wastewater Treatment Act and the Sewage Act. Urban districts develop basic plans for sewage system, and treat household sewage under the Sewage Act, raising the sewage treatment ratio up to 68%. In non-urban districts, each building must maintain its own sewage disposal facility according to the Sewage, Night Soil and Livestock Wastewater Treatment Act. In addition, there are standards for nitrogen and phosphorous in the sewage treatment facilities to prevent eutrophication, and stricter standards are being applied to the upper reaches of major rivers.

Effluents from factories are controlled by the Water Quality Preservation Act, which regulates allowable effluent amounts differentiated by volume (2,000 t/d) and by region. In addition, the Korean government created the pollutant load-based effluent control system in 1994, by introducing the basic effluent charge system.

Effluent standards for wastewater from the livestock farming are regulated by the Sewage, Night Soil and Livestock Wastewater Treatment Act, which applies differentiated standards according to the size of stalls and the region. Particularly, the Korean government has set up public treatment facilities to treat wastewater discharges from small livestock producers, and is constantly expanding its support in order to recycle livestock wastes for fertilizer and other resources.

In 1990, the Korean government designated special measure zones for water quality in 7 cities and counties in Kyunggi Province near Paldang Reservoir (2,102km^2 total) and in Taejon near Daecheong Reservoir, and in 3 counties in Chungchongbuk Province (729 km^2 total) to preserve drinking water resources for residents of Seoul Metropolitan Area and Chungchong Province.

The Korean government limits activities which may result in water pollution by designating 391 regions around major water resources, 1,220 km^2 in total, as protected areas for drinking water supply. It also extends some support measures to residents of those regions in order to compensate them for possible disadvantages resulting from the land-use regulations.

In 1999, the Korean government has established a Riparian Buffer Zone upstream from Paldang Reservoir (255 km^2 in total), where water quality and ecology preservation is essential, and has been restricting the construction of new pollution sources such as restaurants, hotels, livestock facilities, and factories in the zone. It also plans to establish other buffer zones around Nakdong, Keum, and Youngsan Rivers.

There are 1,576 sites of the Water Quality Measurement Network that monitors overall water quality conditions. At the same time, there are 20 automatic water quality monitoring stations in operation to help control monitor and give early warning against pollution accidents. Results of water quality inspection are made public through a monthly official newsletter and via mass media, while water quality data are offered through the internet.

In 1998, Special Measures for the Management of Water Quality in Han River Watershed were established, a policy set which created a basis for mutual prosperity in water quality preservation between the upper and lower reaches of the Han River.

As mentioned above, lands along the banks of the upper Han River, an area of 255 in total, were designated as Riparian Buffer Zones, where the construction of such new buildings as hotels and restaurants is forbidden. Particularly, the government plans to gradually purchase land within the zone, turning it into a green reserve featuring forests and artificial marshes in the form of Eco-park. Additionally, a total maximum loading system of pollutants has been introduced, which has enabled the control of the total quantity of pollutants in the entire Han River watershed. By introducing a water-use charge system in August 1999, which charges 80 won per ton of water use, upstream residents and local governments benefit from the funds collected through the system.

Because the pollution sources are largely distributed in up- and mid-stream and the water flow is low, the government is introducing a total maximum loading system of pollutants to more effectively control the total amount of pollutants. The first target to be subject to the total maximum loading system is going to be biological oxygen demand. The government will later expand the targets to include chemical oxygen demand, nitrogen, and phosphorous as the circumstances permit.

3.2 Contingency Plan for Algal Blooms

Cyanobacterial blooms have been occurred in Korea since the 1990's. These blooms are highly visible and may or may not result in the release of toxins. The major public concern is the production of toxins by certain strains of cyanbacteria. Therefore, in the event of a bloom occurrence, contingency arrangements need to be put in place to ensure the continued acceptability of the water supply. Korean government has carried out Algae Alert System in five lakes which are used as drinking water sources since 1997. The alert levels framework is a basic monitoring and three stage action sequence which operators can use to respond to the onset and progress of cyanobacterial bloom(Table 2).

Table 2 Criteria of Algae Alert System

Level	Criteria
I	• When chlorophyll a concentration of successive samples are between 15–25mg/m^3 and cyanobacterial cell numbers are between 500–5,000 cells/ml

II	• When chlorophyll a concentration of successive samples exceed 25mg/m^3 and cyanobacterial cell numbers exceed 5,000 cells/ml
III	• When chlorophyll a concentration of successive samples exceed 100 mg/m^3 and cyanobacterial cell numbers exceed 106 cells/ml and surface scums form
Release	• When chlorophyll a concentration of successive samples are lower than 15mg/m^3 or cyanobacterial cell numbers are fewer than 500 cells/ml

3.3 Eco-engineering technology using aquatic plants

Advanced wastewater treatment methods are widely used to remove nutrients such as nitrogen and phosphorus which are the main contributors to the eutrophication of lakes. Eco-engineering technology using aquatic plants have been studied in Korea since 1980's. The eco-engineering technology can be divided into in three major categories : aquatic, terrestrial, and wetland concepts. All depend on law of natural sciences such as physical, chemical and biological rections and responses. Aquatic treatment system, that is, artificial pond system has been adopted for treatment of rural household wastewater and small scale livestock farming drainage.

To remove nutrients and suppress algal growth in the lakes, floating macrophyte island system and wetland system has been utilised in Korea. Water hyacinth and reed are widely used in these systems. The plant roots absorb nutrients and filter floating materials. The plant leaves shade the surface and reduce penetration of sunlight to suppress algal growth. In the plant root area, numerous microorganisms eat trapped algae and excrete nutrients or are eaten by larger organisms. So, the floating island system provides good environment for a natural ecosystem to function; plants(producer), animals(consumer) and microorganisms(decomposer) are constituting well organised community and living together in a meticulous food web.

3.4 Air flotation, etc.

As potential short-term remedial actions to control the existing algal blooms, two major technologies are under consideration in Korea. The first technology is algae removal ship which suck and filter algal blooms with water and drain the filtered water to the lake. The other one is autoflotation method which flocculate and remove floated algal scums.

Algae removal efficiency and economical efficiency of pressurized flotation device for removal of algal blooms is currently being investigated by small scale field testing. The mechanism of pressurized flotation device is to jet micro-bubbles and coagulant into the water body, flocculate algal cells and suspended solids with micro-bubbles and coagulant, harvest and remove the floated scums out of water body. Harvested scums are to be composted after addition of organics and used as fertilizers.

3.5 Expert System for Eutrophication Management

Eutrophication of a lake is a complicated phenomenon interwebbed with mass balance of nutrient in- and out-flow, hydrological characteristics of lake, aquatic ecosystem, meteorology, etc. Our team of experts is carrying out a project to develop an integrated eutrophication management system which is composed of data base of basin wide pollution sources, eutrophication model, and also geographical information system. This expert system with artificial brain aims at prediction of algal blooming and giving early warning to relevant agencies so that they can take necessary actions in advance. On the other hand, if water pollution accident takes place, the expert system can trace where the pollutants come from and how much it is, so that enforcement authority can easily disclose any company or facilities violating regulations.

The Korean Ministry of Environment has developed an Integrated Water Policy Supporting System which have sets of data bases, 'Windows' program and GIS to Client/Server system. Modelling programs are equipped with the system and we can conduct water quality prediction modeling of major rivers, based on the pollution control plans and pollutant reduction scenario. So, the Integrated Water Policy Supporting System provides basis for the construction of the expert system.

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Restoration of Eutrophicated Macrophyte-dominated, Shallow Lakes

Bjoern Faafeng[1], Li Yawei[2] and Jonas Fejes[3]

1) Norwegian Institute for Water Research (NIVA), P.O. Box 173, Kjelsaas, 0411 Oslo, Norway

2) Inner Mongolia Environmental Science Institute (IMESI), West street 5, Building New City, 010010 Hohhot, Inner Mongolia, China

3) Swedish Environmental Research Institute (IVL), Box 21060, 100 31 Stockholm, Sweden

Abstract Shallow lakes may follow two different paths when receiving increased inputs of plant nutrients; one leading to phytoplankton blooms and turbid water, the other to dense macrophyte stands and clear water. Main points of the concept of the two alternate stable states are presented in this paper. This concept will be taken into considerations in a lake restoration project in Inner Mongolia, P.R. of China, which is carried out in co-operation between Chinese, Swedish and Norwegian researchers. Other considerations also have to be taken into account like: preventing the lake from changing from a lake to a continuous reedswamp, achievement of high biodiversity, provision of good water quality and a long-term sustainability of the human utilisation of the lake's resources.

Key-words Shallow lake Eutrophication Restoration Alternate stable states Wuliangsuhai

1 Introduction

Deep and shallow lakes tend to have different reaction mechanisms on increased loading with plant nutrients, e.g. phosphorus and nitrogen. While the primary response in deep lakes is an increase in phytoplankton density, to a large extent proportional to the loading of the most growth limiting nutrient, shallow lakes may have more diverse reactions. In shallow lakes, eutrophication may take place not only as algal blooms, but also as luxuriant growth of emergent, floating-leafed and submerged vegetation. These two types of responses tend to appear as alternatives; either the nutrient surplus is utilised to produce algal blooms, or dense stands of macrophytes. In this presentation we will review current concepts of shallow lakes eutrophication in general and relevant measures to restore such lakes. Possible countermeasures to the persisting eutrophication the large and shallow Lake Wuliangsuhai in Inner Mongolia is presented as an illustration of the many different factors that have to be considered before a final action plan can be worked out.

2 Shallow Lakes Versus Deep Lakes

In the last decades major progress has been made in understanding the eutrophication processes of lakes and how to deal with their unwanted effects, such as turbid waters, surface scums, toxic bluegreens, oxygen depletion, fish and bird kills and dense macrophyte stands. Lake eutrophication is recognised as one of the major environmental problems related to human activities. Once humans settle in an area and development of agriculture and industry takes place, increased loading of nutrients to the nearest rivers or lakes will often be the result. Hence, gradual or abrupt increase in nutrient concentrations in the water can be expected, inducing the processes of eutrophication. Already in 1974 Dillon and Rigler (1974) found a linear relationship between the P-concentration of deep, temperate lakes and the concentration of phytoplankton in their surface waters (measured as chlorophyll-a). Despite a considerable scatter in the P vs. Chl-a plot, this simple model has been one of the most useful tools to understand the basic mechanisms of eutrophication of deep lakes and has been the basis for more sophisticated models like the phosphorus loading concept of Vollenweider (1975). Whole-lake experiments in Canada also established the fact that phosphorus is normally the basic growth-limiting nutrient in deep, temperate lakes (Schindler 1977). Gradually, however, it became clear that more complex processes had to be understood when protecting and restoring shallow lakes from eutrophication.

3 Two Alternate Stable States

Given a lake shallow enough for the growth of plants attached to or rooted into the sediment, beds of submerged, floating-leafed and emergent vegetation will gradually develop. When surplus nutrients are added from the catchment this development is speeded up and the macrophyte beds may become dense enough to reduce the biodiversity of the system and fill up the water body to such extent that human use to e.g. drinking water and transportation is hampered. However, it has been noted that in such dense macrophyte dominated systems, the water often remains clear despite high loading with nutrients. If these dense macrophyte stands are damaged physically, shadowed out by high turbidity or removed, the formerly clear waters may turn turbid due to blooms of phytoplankton.

Once the system changes from clear to turbid, a new "stable state" seems to have established, and the lake tends to remain turbid over many years. On the other hand, a turbid state may "switch" back to a macrophyte dominated, clear water state. Natural stress situations like extremely low water level (Blindow 1992) or selective feeding on plants by birds (van Donk and Gulati 1995) may result in switching. Without going into details about the mechanisms, we will mention that grazing on phytoplankton by Daphnia, and resource limitation of phytoplankton is often involved in the switching and buffering. For more details about the mechanisms by which these concepts work, we refer to literature. As the clear water state is normally considered to be the most useful and valuable one, a lot of research has been carried out to understand the concept of "the two stable states" and its "switches" and "buffers" (see review by Moss 1998, and references therein).

While "switches" in this connection is referred to as mechanisms by which a change from one of the stable states to the other is promoted, "buffers" are those mechanisms which stabilise each of the two stable states. Understanding these mechanisms is, therefore, decisive when setting up a feasible restoration plan for eutrophicated, shallow lakes. Moss (1998) has summarised the buffers of the two stable states, respectively, and these are presented slightly modified in Table 1.

Table 1 Buffers of the two stable states of shallow lakes (modified from Moss 1998)

Plant-dominated (clear water) stage	Algal-dominated (turbid water) stage
• Suppression of eddy currents	• Possibility of vigorous wind mixing
• Luxury uptake of N and P	• Algae compete well with plants for nutrients, CO2 and light
• Water chemistry unfavourable to fish	• Structureless habitat with no refuge for large zooplankton grazers
• Structural refuges for large zooplankton grazers	• Small algal species with high light absorption
• Habitat for periphyton grazers	• Sediment poorly suitable for plant regeneration
• Allelopathy	• Stimulation of small, planktivorus fish
• Firm, structured sediment	
• Balance between planktivorus and predatory fish	

Switches between the two states are given in Table 2. It is pinpointed that reduction of nutrient loading by itself is not considered a sufficient measure to induce a switch from the clear to the turbid water stage in shallow lakes, a fact which is different from the situation in deeper lakes.

Table 2 Switches between the two stable states (modified from Moss 1998)

From clear to turbid state	From turbid to clear state
• Destruction of plants:	• Alteration of the fish community to promote large zooplankton grazers
Mechanical harvesting	Removal of planktivore fish
Boat damage	Stocking of predatory fish
Herbicides	• Reduce nutrient inputs
Grazing by cattle, birds, fish, crayfish	Reduce pollution
Raising of water level	Reduce release from sediments
• Interference with buffer mechanisms	• Lower water level
Reduce zooplankton activity by toxins	
Increase salinity above 5 o/oo	
Reduce predatory fish by O2 depletion or overfishing	

4 Lake Wuliangsuhai

The large and shallow Lake Wuliangsuhai, situated in the Autonomous Province of Inner Mongolia, P.R. of China is described by Li et al. (this symposium). A comprehensive project is established to analyse the pollution sources, the nutrient and contaminant loading of the lake and the eutrophication situation. The outlines of the project is presented by Fejes et al. (this symposium). In the current presentation, we will discuss some possible remedial actions that may be useful for the restoration of the lake. We stress that the project, which was started in 2000, will provide a final action plan of cost-efficient measures before 2004. The final plan will be based upon thorough analysis of the collected data. Below, possible restoration measures are connected to their respective long-time goals for the management of the lake.

4.1 A major goal of the project is "to keep the lake as a lake"

This means to slow down or stop the expansion of the reedbelts. Today reed (*Phragmites* sp.)

and bulrush (*Typha* sp.) cover 50% of the lake surface (ca. 150 km^2), and all the plant biomass extending above the ice during winter is harvested for the production of paper and greenhouse mats, respectively. This harvest removes a large amount of organic matter and nutrients, and is considered to retard the expansion of the reed. For the local and regional society, the lake is in this way an important source of raw materials (reed and bulrush, fish etc.). It is therefore a long-time goal to maintain the productivity of the lake for the benefit of the people in the area. Continuation of the reed harvesting is likely to have positive effects.

Likewise, partial harvesting of submerged vegetation may also reduce the accumulation of organic matter and nutrients in the lake. Today a major part of the lake that is not covered by reed consists of dense beds of submerged vegetation, dominated by sago pondweed (*Potamogeton pectinatus*). Experiments are carried out during summer 2,000 to harvest submerged vegetation, which will be dried and utilised as feed for domestic animals (sheep etc.). Today it seems unlikely that this harvesting may be extensive enough to let the lake switch from a clear to a turbid state, however, this is a possibility that should be carefully considered, according to the concept of two alternate stable states.

Over time the lake will inevitably become gradually more shallow and turn to a reedswamp and later to dry land. Slowing this process is possible by increasing the water depth of the lake. Since raising the water level will flood large areas in this flat floodplain landscape, dredging may be more feasible. However, even partial dredging of a lake of this size may be too expensive, if no other considerable benefits may be achieved. One possible achievement might be that the sundried sediment could be used to improve the saline soils in the area to provide new basis for agricultural production.

4.2 The water of the lake and its tributaries should have a good quality

This goal implies that measures should be taken to reduce pollution both from point sources (domestic sewage, industry) and diffuse sources (run-off from agriculture). Today the lake receives water heavily polluted from the 7,000 km^2 Hetao Irrigation Area. Especially the loading of nutrients (P and N), particles, dissolved organic matter and mineral salts is high, while inputs of metals and organic contaminants appear acceptable. The most obvious task to improve the water quality of the lake is to identify and reduce the most important sources of pollution, both point sources and diffuse sources. Until now it seems that priority should be given to reduce the loading of plant nutrients and organic substances. Distributed treatment of effluents and run-off close to the sources should be preferred.

Further increase in the input of mineral salts should also be avoided. In this area with dry and hot summer climate a major part of the irrigation water taken from Yellow River is lost by evapotranspiration, leading to increase in the salt content in the run-off to the lake. Also from a water-scarcity point of view of the whole Yellow River hydrological system, it is obvious that a more efficient utilisation of the irrigation water will be necessary in the long run.

Flushing of relatively unpolluted water from the Yellow River directly through the lake may be a useful tool for reduction of the nutrient content of the lake, both by direct dilution and by adsorption of nutrients to fine particles from the river water.

One point, which should not be overlooked, is that the dense reedswamps near the main inlet protect a major part of the lake from the turbid and polluted water from the catchment. By slow, natural infiltration through the reed, particles settle and nutrients and contaminants are inactivated. It seems clear that cutting of open canals through the reed from the inlet to other distant parts of the lake, thereby creating shortcuts for water through-flow, should be avoided.

4.3 Another goal is to achieve a high habitat diversity and biodiversity of the lake

Achievement of this goal will stimulate the total lake productivity and lead to a more sustainable system. Also high habitat diversity is a prerequisite for the rich birdlife in and at the lake. A large population of birds (geese, ducks, gulls, herons, wading birds etc.) spend the summer breeding at the lake, but the lake also serves as an important “stepping stone” for feeding and resting of migrating birds on their way to and fro their breeding areas further north. Among the birds found at the lake, several are redlisted as rare or threatened species.

A general increase in habitat diversity of the lake seems favourable. Larger areas of open water than today, dredging of some deeper basins and construction of a number of “islands” of reed surrounded by open water are examples of possible measures that would be positive to the lake ecosystem from a theoretical point of view.

The drastic reduction in fish catch in the lake over the last decade indicates that some factor related to fish reproduction or survival is seriously affected. The restricted area of “open water” without vegetation may be one decisive factor. Another may be oxygen depletion under the ice during winter. Winter survival and decomposition of submerged vegetation should therefore be studied in addition to studies of fish species dominance and age structure in the lake.

Introduction of new species of fish to increase food production has long traditions in China. Such introductions may nevertheless lead to unexpected consequences for the rest of the ecosystem and should be carefully assessed. Drastic changes in the fish population may affect the “buffers” of the clear water stage which persists in most areas of the lake, except those close to the main inlet.

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Management Plans for Eutrophicated Lakes Using Logical Framework Approach (LFA) — The Lake Wuliangsuhai case, Inner Mongolia

Jonas Fejes [1], Li Yawei[2], and Bjoern Faafeng[3]

1) Swedish Environmental Research Institute (IVL), Box 21060, 100 31 Stockholm, Sweden

2) Inner Mongolia Env. Science Institute (IMESI), West st. 5, Building New City, 010010 Hohhot, Inner Mongolia, China

3) Norwegian Institute for Water Research (NIVA), P.O. Box 173, Kjelsaas, 0411 Oslo, Norway

Abstract Although volumes having been written on eutrophication and lake restoration there is not, and most likely never will be, a blueprint for lake restoration programme. The design of lake restoration programmes vary from simple 'desk-top' design to a collaborative design exercise involving multiple stakeholders. Designs can be brief, uncomplicated exercises that last only hours or long complex procedures that involve many cycles, or iterations, of planning, reviewing and adjusting. This paper is designed to assist lake restoration designers and lake managers to understand how to use the logical framework approach for a lake restoration project. The Lake Wuliangsuhai, Inner Mongolia, will act a practical example. The most conspicuous problem with lake Wuliangsuhai is that the lake surface is rapidly giving way for reed beds that today cover roughly half of the lake. A closer look reveals typical eutrophication characteristics with deteriorating water quality in terms of higher nutrient status, high biomass production causing high sedimentation rate of organic matter, which in turn leads to increasingly shallow waters where reed beds can take root, and so on. The eutrophication of the lake is a result of large amounts of nutrient inputs from the Hetao area, which is an intensively cultivated agricultural plain entirely dependent on irrigation water from the Yellow River. On the basis of the mini “Logical Framework Approach” (LFA) workshop that was carried out during the Swedish-Norwegian mission to Inner Mongolia in September 1997 the focal problem was identified as “unsustainable water usage in Hetao area”. This problem is caused primarily by “conflicting interests between different usage of the limited water resources” “lack of knowledge about the actual situation of the lake and the catchment area” and “deficient management skills and facilities for local sustainable water usage”, and the result is “deteriorating lake water quality” leading eventually to that the “lake disappear”.

Key-words Logical Framework Approach Lake restoration

1 Introduction to an Effective Project Design

The logical framework (or logframe) approach provides a set of designing tools that, when used creatively, can be used for planning, designing, implementing and evaluating projects. Logframes provide a structured, logical approach to setting priorities and determining the intended results and activities of a project. Used correctly, logframes can provide a sound mechanism for developing a project concept into a comprehensive project design document. Logframes can also provide the basis for evaluating the effectiveness, efficiency and relevance of a project. There are a variety of approaches to logframes. Many of the institutions involved in conservation and development activities have particular approaches to logframes. This paper does not argue that one approach is better than another, but provides a generic approach that can be adapted to suit the needs of the user or donor agency. The logframe approach usually consists of an analysis and a planning phase, each phase has three steps as shown below (adapted from ITAD, 1996).

Analysis Phase	Planning Phase
Analysis of problems	Logframe
Analysis of Objectives	Activity Schedule
Analysis of Strategies	Input and cost schedule

Before describing the logframe approach it is worth considering what needs to be undertaken before a logframe can be developed.

1.1 Situation analysis

Before the logframe approach can be used the situation of the proposed project or programme needs to be analysed. Answers to the following questions are needed:（1）What are the general areas of concern, or themes, that the project will focus on?,（2）What is the project aiming to achieve?,（3）At what spatial levels will the project focus, in terms of subject (broad/macro to specific/micro) and or geography (local to global)?,（4）What political, socio-economic, technological and biophysical environment will the project operate within?,（5）Who are the major stakeholders?,（6）How will stakeholders be involved in the process of design, implementation, monitoring, evaluation and reporting?,（7）Who is working on the issues already? What are they doing?,（8）What is the niche of the project?,（9）Who will implement the project?,（10）What is the intended duration of the project?,（11）What is the anticipated level of funding?, and（12）Who will fund the project? Before a logframe can be developed the answers to many or all of these questions need to be collected, synthesised and analysed.

In addition, the project needs to be placed in the context of the following four areas of concern:（1）The historical background of issues relating to the proposed project,（2）The current situation,（3）The needs and interests of various stakeholders, and（4）Future options. For projects involving simple issues the information collection, synthesis and analysis stage is often very brief. In other instances, where the project is complicated, the information collection, synthesis and analysis stage requires intensive efforts that can take years.

1.2 Getting ready for the logical framework workshop

Ideally the logical framework analysis should be undertaken in a workshop situation which includes key stakeholders. However, more often than not, the logical framework is developed by a consultant or staff member in isolation from other stakeholders. This latter approach should be avoided where possible. Before commencing the logframe workshop the above preliminary steps should be complete and the following issues should be considered: （1）Who will be involved in the logframe workshop?, （2）Where will the workshop conducted?, （3）Who will facilitate the workshop?,（4）What background materials, papers and expertise may be needed for the workshop?, and（5）What materials and logistics are required? In some situations more than one round of logical framework analysis may be needed. This is particularly the case where there are large differences of opinion between stakeholders. Such differences can be geographic, social, economic or political. For example, a project may be focused on assisting village communities to manage natural resources while operating simultaneously at district, regional and national levels. Bringing stakeholders together from the national policy level to the resource user level in a single logframe exercise is unlikely to be feasible or productive. An alternative approach involves using a participatory approach to planning at the village level which feeds into a series of logframe workshops at the higher levels. The outcomes of the participatory planning exercises and workshops can be fed into an overall project logframe workshop at the national level involving key stakeholders national, regional, district and grassroots organisation levels.

1.3 The analysis phase

The logframe approach begins by analysing the existing situation and developing objectives for addressing real needs. The analysis phase is the most critical, yet most difficult, phase of the logframe approach. The analysis phase consists of three stages, analysis of problems, analysis of objectives and analysis of strategies.

1.4 The analysis of problems

The analysis phase usually begins with an analysis of problems. However, beginning the process with an analysis of problem can produce poor results as it focuses on negative issues to begin with. This can be a particularly serious problem in cultures that consider it inappropriate to openly discuss problems or criticise. An alternative is to begin by formulating objectives, this is discussed below. The problem analysis is undertaken by identifying the main problems and developing a 'problem tree' through an analysis of cause and effects. Identifying the main problem Brainstorming techniques are used to identify the main problems. Before the brainstorming exercise commences it is important that the facilitator explain the process and the group agrees on some rules for brainstorming.

An example of brainstorming rules

- All ideas are accepted without argument
- Aim for quantity rather than quality
- No debate about whether ideas are accepted or not, only about whether the idea has already been listed.
- No evaluation now (limit the discussion on the significance of the material and concentrate on getting full cross-section of ideas)

For maximum participation, brainstorming groups should be no more than ten or twelve people. For larger groups it is better to split the group into smaller groups. The brainstorming exercise commences by asking workshop participants to identify the main problems that the project will address. The main problems should be written on small pieces of card, post-it notes, or paper and stuck on the wall. Wherever possible high order problems should not be described as “lack of” something, for example lack of knowledge, but instead they should be described as an effect, for example lack of knowledge may become “destructive forest harvesting practices”. After all of the problems are displayed on the wall they should then be clustered into groups of similar issues. Problems that are duplicated can be discarded. At this stage a simple “weeding” exercise can be undertaken. The aim of the weeding exercise is to remove any problems that are clearly not problems that can be addressed by the project.

1.5 Developing the problem tree

The problem tree is developed by moving problems from the clusters of problems on the wall and by adding new problems that emerge as the tree is developed. Problems can be moved up or down the tree as required. The tree should end up with one main problem and a series of lower order problems that branch out below the main problem. The easiest way to develop the problem tree is to begin with a “starter” problem and progressively add the other listed problems to the tree. It does not really matter which problem is chosen as the starter problem but it is best if it is a problem that participants agree is of major importance. The problem tree is constructed by selecting a problem from the list and relating this problem to the starter problem using the cause-effect rationale described below: (1) If the problem is a cause of the starter problem it is placed below the starter problem, (2) If the problem is an effect of the starter problem it goes above, and (3) If it is neither a cause or effect it goes at the same level.

1.6 Objectives analysis

The problem tree is transformed into an objectives tree by restating the problems as objectives. ITAD (1996) describe the objectives tree as the positive mirror image of the problem tree. It is usually necessary to reorder the position of objectives as you develop the tree. The objectives tree can also be considered as an “ends–means” diagram. The top of the tree is the end that is desired and the lower levels are the means to achieving the end.

1.7 Strategy analysis

The strategy analysis involves clustering objectives and examines the feasibility of different interventions (ITAD, 1996). The main objective becomes the project purpose and the lower order objectives become the outputs or results and activities.

Fig. 1　The logical framework matrix

Objectives/activities	Indicators	Means of verification	Assumptions
1 Overall Objectives	15 Indicators	16 Means of verification	8 Assumptions
2 Project Purpose	13 Indicators	14 Means of Verification	7 Assumptions
3 Results	11 Indicators	12 Means of Verification	6 Assumptions
4 Activities	9 Means and Indicators	10 Costs and Means of Verification	5 Assumptions

2　The Planning Phase

The logframe matrix is developed from the strategy analysis by filling in the columns of the matrix as shown below. The objectives, purpose, outputs/results and activities are transposed from the strategy tree to the columns and rows in the matrix. Figure 1 indicates the approach to preparing a logframe and indicates the sequence for completing the logframe. ITAD (1996) suggest that when used properly the logframe helps to make logical relationships between activities, results, purpose and objectives more transparent.

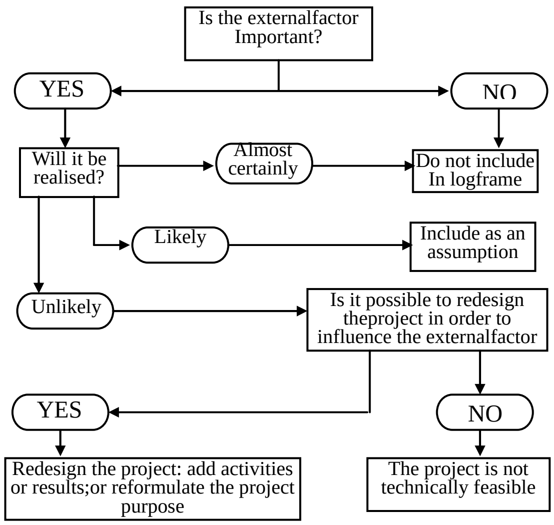

Fig. 2　The Assumption Algorithm (ITAD, 1996)

Assumptions

The aim of specifying the assumptions is to identify the external factors that will affect the success of the project. Once assumptions have been identified, they are stated in terms of the desired situation (ITAD, 1996). ITAD provides an assumptions algorithm shown in figure 2.

3　Objectively Verifiable Indicators

For each output and activity indicators need to be developed. Objectively verifiable indicators or OVI should meet the following criteria:

Measurable	An indicator must be able to be measured in either quantitative or qualitative terms
Feasible	An indicator should be feasible in terms of finances, equipment, skills and time.
Relevant and accurate	And indicator should reflect what we are trying to measure in an accurate way.
Sensitive	An indicator should be capable of picking up changes over the time period that we are interested in.
Timely	An indicator should be able to provide information in a timely manner.

At this stage in the logframe process there is often a tendency to include large numbers of indicators on the assumption that more information is better than less information. Prescott-Allen (1997) differentiates between performance indicators and descriptive indicators. Performance indicators measure the achievement of objectives. For example, the % annual change in forest area; life expectancy at birth. Descriptive indicators measure phenomena that may influence objectives but which the objectives are not expected to change. For example, national monthly rainfall index; ethnic composition of population. Prescott-Allen (1997) provides the following details about indicators: （1）Performance indicators measure results and responses,（2）Results are more convincing indicators than responses,（3）The more direct the indicator the more reliable it will be,（4）Conditions or states are the most direct measures of results,（5）Pressures are strong substitutes for conditions/states,（6）Responses are weak substitutes for conditions/states.

He continues, a high quality performance indicator:（1）Relates to an explicit objective,（2）Accurately and unambiguously reflects the degree to which the objective is met,（3）Is measurable,（4）Depends on data that are either readily available or obtainable at reasonable cost,（5）Is analytically sound and uses standardized measurement wherever possible to permit comparison, and（6）Shows trends over time and is responsive to changes in conditions and sensitive to differences between places and groups of people.

Means of Verification

Once indicators have been developed, the source of the information and means of collection (means of verification (MOV)) should be established for each indicator. An MOV should test whether or not an indicator can be realistically measured at the expense of a reasonable amount of time, money and effort. The MOV should specify: ⑴The format in which the information should be made available (e.g. reports, records, research findings, publications), ⑵Who should provide the information, and ⑶How regularly it should be provided (adapted from ITAD, 1996).

4 The Lake Wuliangsuhai, Inner Mongolia

On basis of the mini LFA workshop that was done during the Swedish-Norwegian mission to Inner Mongolia in September 1997 the focal problem was identified as “unsustainable water usage in Hetao area”.

The problem is caused primarily by “conflicting interests between different usage of the limited water resources” “lack of knowledge about the actual situation of the lake and the catchment area" and "deficient management skills and facilities for local sustainable water usage", and the result is "deteriorating lake water quality" leading eventually to that the "lake disappear" (see Figure 3). The project has so far revealed conflicting interests between the use of the lake as a recipient for agricultural drainage and municipal waste water, for production of reeds, for fishing, and keeping the lake as a lake. The wish of the local government (Bayannor League of Inner Mongolia) is to keep the lake and make it more productive, while at the same time reduce the input of nutrients from municipalities, agriculture and industry. Behind human induced eutrophication problems lie unsustainable water utilisation, leading to yet sharpening conflicts between different uses and users of a limited water resource. As long as water management authorities fail to take the available water resource as starting point for distribution and regulation of water, and instead seek solutions to water problems in increasing the supply, water related conflicts are bound to increase. What is needed therefore is a shift towards water management that starts from the available water

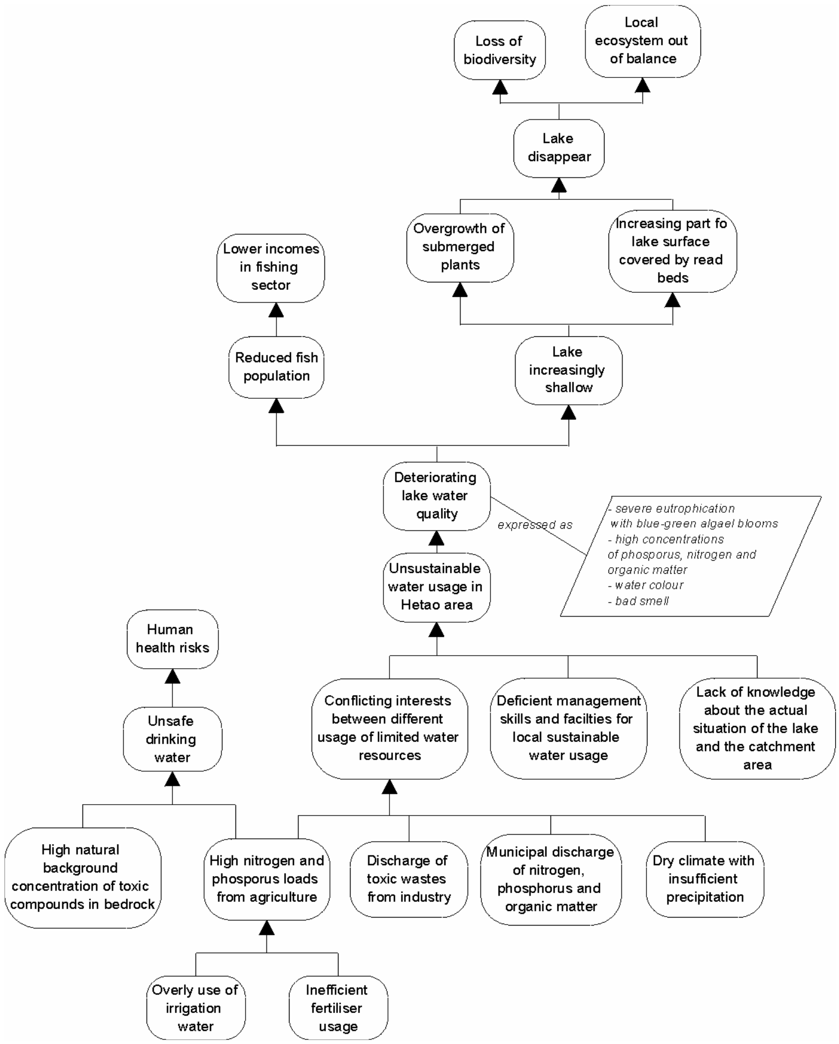

Fig. 3 A problem tree for the eutrophicated Lake Wuliangsuhai

resource and devote its efforts on managing the conflicting demands for a limited resource. The purpose of the Inner Mongolia Lake Restoration Project is to facilitate the establishment of sustainable water usage in the Hetao area by building a maintainable knowledge base on the natural and societal processes that affect the water quality, qualifying the Chinese personnel in relevant topics and skills, and produce a feasible management and control proposal for addressing the conflicting interests that cause the eutrophication problems of Lake Wuliangsuhai.

5 Conclusions

The logical framework approach provides a powerful set of tools for designing projects and project evaluations, as for restoration of eutrophicated lakes. However, like all tools, logframes are not the complete answer to effective project designing. Logframes are best used towards the end of the project design cycle after information has been collected and analysed, needs assessed, views of stakeholders sought and the external environment of the project understood. In situations where the problem identification stage is likely to be a problem in itself, the search conference and the intent structure may be more appropriate approaches for the analysis phase.

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Strategic Planning. A Tool for Eutrophication Prevention and Control in the Binational Basin of the Bermejo River

Alberto Calcagno

Water Resources Environmental Management-Faculty of Engineering-University of Buenos Aires-Argentina

Abstract Eutrophication of lakes and reservoirs has usually an anthropogenic origin resulting from man's intervention in the drainage basin environment. Control of non-point sources as well as the implementation of waste reduction measures in domestic and industrial processes. are the main challenges towards eutrophication abatement. Preventive management of pollution and contaminant loads requires a holistic approach, involving integrated water management at watershed level. Some key issues which are fundamental to achieve sustainability in terms of social acceptance, economic efficiency and ecological integrity are⑴watershed approach, ⑵strategic planning, ⑶social negotiation mechanisms, ⑷regulatory framework, particularly land and water use regulations and ⑸informed decision processes for project development. In Argentina, with exception of a limited number of water bodies, the majority of lakes present good mean water quality conditions. Thus, besides taking actions concerning the more critical situations, it becomes evident that there is a need to address preventive measures to avoid further deterioration of polluted environments and, most relevant, to maintain good quality conditions where they presently exist. Recently the governments of Argentina and Bolivia completed the formulation phase of an Strategic Action Program for the Binational Basin of the Bermejo River Basin (SAP), which constitutes the starting of a positive approach to that end. Anticipating the construction of infrastructure actions for water resources development and utilization, including proposed reservoirs for low flow augmentation, a Strategic Action Programme has been elaborated for the Binational Basin of the Bermejo River addressing the above mentioned strategic key issues necessary to conduct an integrated management of water resources and consequently, prevent and control eutrophication.

1 Eutrophication Prevention

Eutrophication of lakes and reservoirs has usually an anthropogenic origin resulting from man's intervention in the drainage basin environment. Increased loads of nutrients and other pollutants, and/or the alteration of natural physical and biogeochemical conditions in the watershed generally trigger eutrophication processes, overcoming the resilience of the natural system. Therefore eutrophication management should be focused in the prevention and reduction of pollution from point and non-point (diffuse) sources. Control of non-point sources as well as the implementation of waste reduction measures in domestic and industrial processes. are the main challenges towards eutrophication abatement. The control of point sources has available nowadays a variety of end-of-the-pipe and environmental technologies suitable for most common situations. Cost effectiveness, financing and cost allocation among beneficiaries are the major constraints in this case.

The world needs more food. The expansion of irrigated or rainfed food production and of urban settlements is and will continue increasing the pressure on land and water resources. Unsustainable land and water management practices in rural and urban areas, enhanced by poverty conditions and lack of financial resources, enhance degradation of watershed environment, further increasing the supply of sediments, nutrients and toxic substances into river systems, lakes and reservoirs. Eutrophication problems will then continue increasing world wide. Although it is universally accepted that its cheaper to prevent rather than to remediate, the bibliography is plenty of examples and case studies where remediation measures are discussed. Lessons learned are generally oriented to assess and improve restoration methods (management of external sources -technology applied to the diversion and treatment of polluted inflows-, and in-lake management measures - sediment removal, bio-manipulation, etc.) rather to promote prevention measures. Long term future benefits have low present value.

Preventive management of pollution and contaminant loads requires a holistic approach. Eutrophication prevention, as well as remediation and control involves integrated water management at watershed level. Integrated is used here as a multidimensional concept which calls for the simultaneous consideration of natural resources, social, cultural, institutional, regulatory, economic and political issues in the watershed.

Integrated water management for eutrophication control implies simultaneous implementation of top down and bottom up measures in the social system. Top down measures involve the incorporation of environmental concerns into policies, planning and decision making at the highest level and from there downwards to ensure the effective dissemination of said principles and strategies into the institutional and regulatory frameworks of all existing jurisdictions sharing the basin.

Bottom-up measures involve incorporating those same concerns into civil society at community level. Education for sustainable development, public information and public participation should provide the necessary momentum to produce a positive cultural change to support the strengthening of the top down process, ensuring the effectiveness of the institutional and regulatory framework and the achievement of the established goals. Both approaches should be carried out simultaneously since they are complementary and convergent.

2 Some Key Strategic Issues for Eutrophication Prevention and Control

Sustainable management of fresh water resources involves a variety of economic, social and ecological issues and conditions which need to be fulfilled at the same time to ensure present human development without impairing the possibilities of future generations.

In short it brings about the need to ensure that the economic, social and environmental value of water is duly accounted for in every decision concerning development and use of water and other natural resources as well as in any activity having direct or indirect effects on water resources, which are the most.

Since said water values cannot all be expressed in monetary terms[1], decision making should strongly rely on the assessment of social perceptions and preferences. Some key issues to ensure a proper assessment of said values, which are fundamental to achieve sustainability in terms of social acceptance, economic efficiency and ecological integrity are ⑴watershed approach, ⑵strategic planning, ⑶social negotiation mechanisms, ⑷egulatory framework, particularly land and water use regulations and ⑸informed decision processes for project development.

2.1 Watershed approach

To achieve an environmentally sound, management of water resources directed to prevent and control eutrophication it is necessary to integrate *biogeophysical, social and economic* issues, accounting for the various aspects concerning water resources availability and uses, including the economic and social aspects related to the degradation of water quality. The watershed concept, in facilitating physical unit for the development of water management scenarios, provides a sound geographic context and an useful qualitative and quantitative basis for sound water planning and management, including the consideration of upstream downstream issues which are inherent to waters resources management.

The watershed provides also the physical unit for a cross-sector approach to surface and groundwater water quality and quantity involving land use and industrial and agricultural development. Also it facilitates the integration of planning, management and operation, which will promote actions more effectively and provide feedback mechanisms to the planning sector.

2.2 Strategic Planning

Strategic planning seeks to establish specific and alternatives goals for the integrated multipurpose development and environmental protection in the basin, including eutrophication prevention. Timing, financing mechanisms and required legislative framework are integral components of the strategic plan. It should be based on a sound appraisal of environmental (biogeophysical and social) problems, their root causes and account for alternative future scenarios. The causal chain linking existing problems with roots causes should be developed properly based on a participatory process involving stakeholders. The same applies to the identification and characterization of the root causes which reflect the policy, institutional, economic and social context determining the way in which landscape is intervened and environmental goods and services in the basin managed. Based on said inputs, a holistic strategic framework addressing the basic causes of environmental degradation, including eutrophication, will come out from the planning process, providing a useful tool to guide priority prevention and remediation actions and

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[1] Despite many efforts devoted to research and case studies analyses, methodologies to assess use, option and intrinsic values of environmental assets, goods and services, provided by terrestrial and aquatic ecosystems, need further development as well as a huge amount of data for quantitative analysis rarely available in developing countries.

decision making.

Strategic planning also provides the context for basin wide sound management of water resources allocation among the various sectors demanding water, taking in account the economic, social and environmental value of water.

2.3 Social negotiation

A variety of stakeholders in the basin including governmental agencies, private entities, no governmental organizations, user groups, academy, politicians, civil society organizations in general and community should have the chance to participate in the decision process concerning the use and protection of water resources and strategic planning. Decision making should based on decentralized multilateral deliberations, which is best achieved by some sort of collegiate organization such as a basin committee or agency, where representatives of the various stakeholders will participate. Said organization should intervene in the proposal, analysis and approval of plans and investment programs concerning the environmental protection and water resources development of the basin. This mechanism will better ensure a sound assessment of water values favouring social acceptability and sustainable decision making at watershed level.

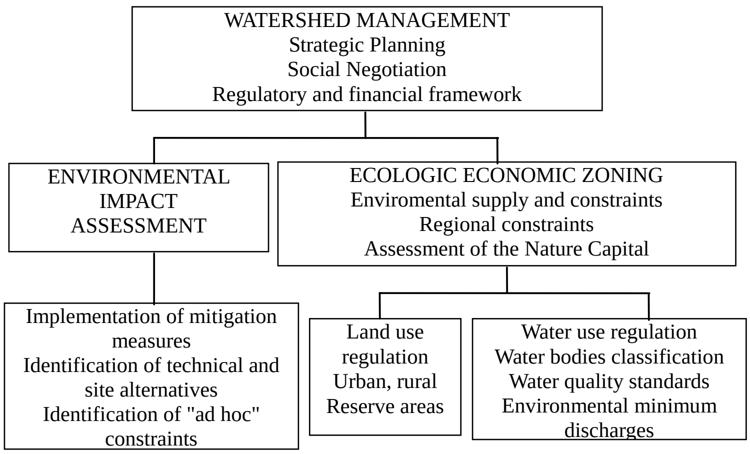


Fig. 1 Watershed Management: Integration of management tools Adapted from [2]

2.4 Regulatory framework

Strategic planning require a regulatory framework to ensure the functional and sustainable implementation objectives and goals, and in particular pollution prevention programs to control eutrophication. Complementary it becomes imperative to strengthen and build technical and institutional capacity to address environmental priorities. Land and water use planning, together with environmental impact assessment procedures, are key instruments to establish objective grounds for decision making within the basin organization, as depicted in Figure 1. Also the establishment of appropriate design standards, water-quality objectives, discharge consents and natural resources management laws are key elements of any pollution reduction program (UNCED,1992).

Economic incentives should be also considered within the management tool set to encourage the adoption of technologies focusing on pollution prevention, as well as efficient and sustainable water allocation. They include, among others, property rights, water markets, fiscal and financial instruments, charge systems and liability systems.

2.5 Informed decision processes for project development

There is a need to ensure the incorporation of community expectancies and perspectives into project development since the early stage of the process. A comprehensive database and sound knowledge of processes and interaction between the project and the environment (biogeophysical and social); best appropriate technologies promoting efficient use of water and minimizing wastes; incorporation of environmental concerns (externalities) into project design and budget and public consultation and participation are central to achieving sustainability at project level. Public participation, requires access to information and capacity to understand relevant issues by the community. Decision Support Systems are modern tools based on simulation and optimization models, real time data gathering systems and user friendly operation which may be helpful in integrating the key components of an informed decision process at project level as well as in the strategic planning process.

3 The Bermejo River Basin Approach

A number of lakes and reservoirs in Argentina are subject to water quality degradation from rural, urban and industrial activities. Eutrophication, dissolved oxygen depletion, microbiological pollution, toxic pollution, aquatic biota impairment are the major problems affecting water quality. A few of them present generalyzed hypereutrophic or eutrophic conditions, linked to massive raw effluents of industrial origin in one case and sewage inputs from a urban settlements and agricultural activities in others. A major part of the remaining lakes and reservoirs present mesotrophic and oligotrophic conditions, with localized temporary eutrophication episodes in a number of cases. This episodes result in algal blooms, in some cases of toxic blue-green algae. Therefore, with exception of a limited number of water bodies, the majority of lakes present good mean water quality conditions.

Thus, besides taking actions concerning the more critical situations, it becomes evident that there is a need to address preventive measures to avoid further deterioration of polluted environments and, most relevant, to maintain good quality conditions where they presently exist. Since most river-lake systems in Argentina are shared by two or more provincial administrations, integrated water resources management becomes more complex and at the same time more stringent. Addressing the key issues mentioned above becomes fundamental to prevent and control eutrophication.

Recently the governments of Argentina and Bolivia completed the formulation phase of an

Strategic Action Program for the Binational Basin of the Bermejo River Basin (SAP)[1], which constitutes the starting of a positive approach to that end.

3.1 The Binational Bermejo River Basin (BRBB)

The BRBB extends over some 123,000 km^2, originating in the Andes Mountains of northwestern Argentina and southern Bolivia. (See Figures 2–4). The river, which flows some 1,300 km, crosses the Chaco Plains, forming an important ecological corridor linking the Andean ecosystem with the Atlantic ecosystem. Because the Bermejo River is the only major river spanning the Chaco, the river system contributes the largest mass of Andean sediment to the Plata River system. The origin and behavior of the sediment has the potential to dramatically condition water uses in the Bermejo and Plata river systems, not only with respect to river-based and river-dependent activities but also with respect to the structure and dynamics of the riverine ecosystems

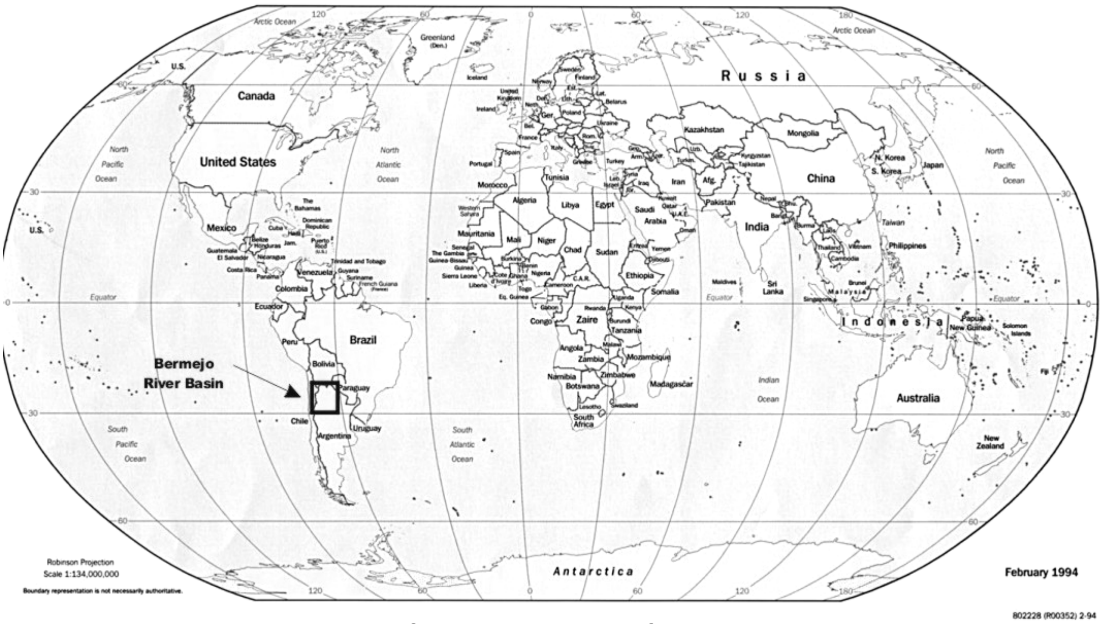
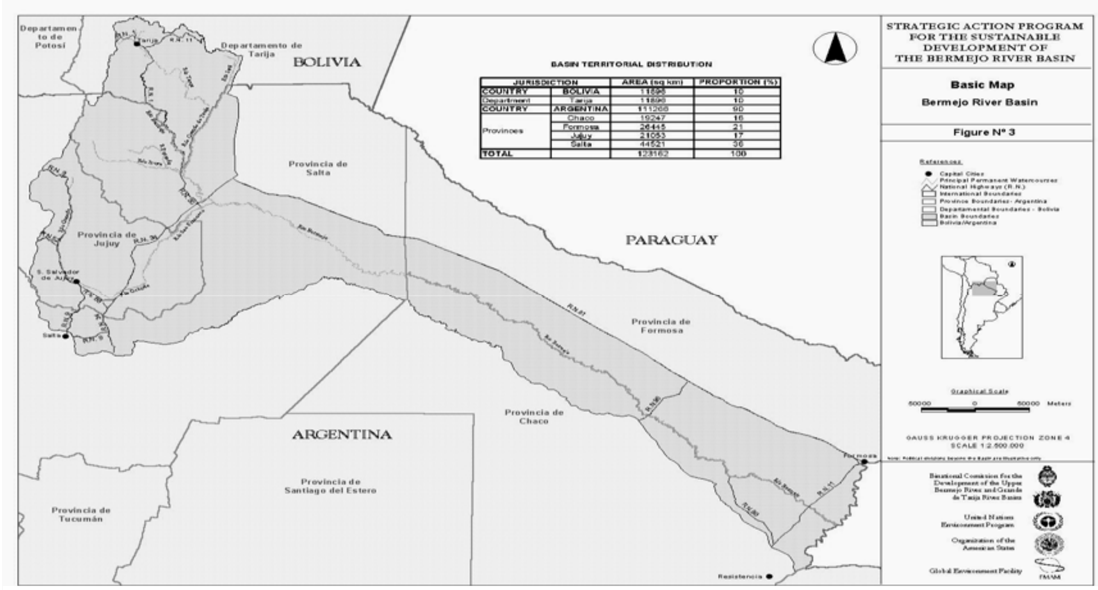


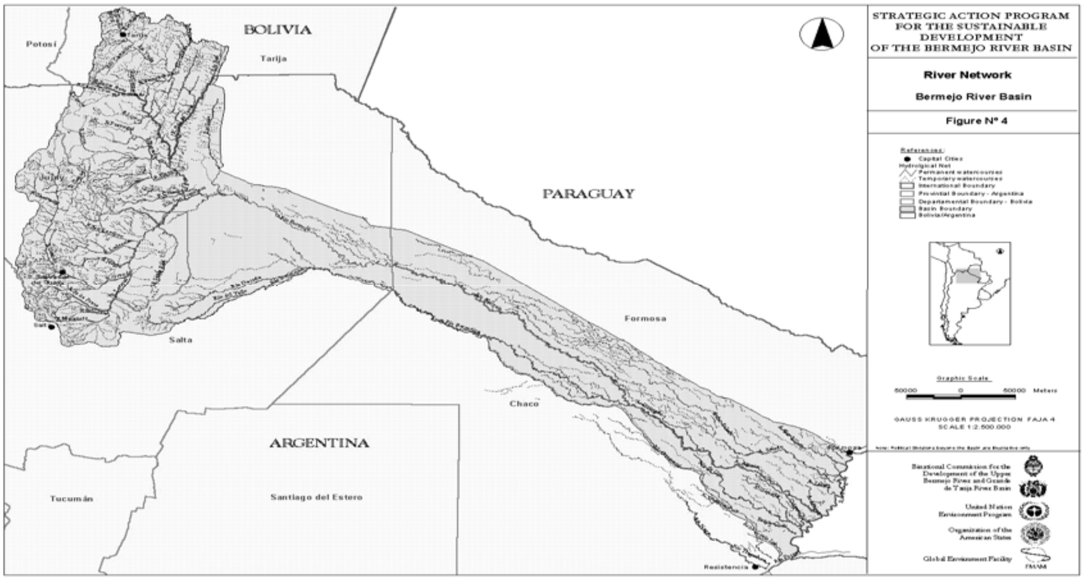
Fig. 2 Location of the Binational basin of the Bermejo River

3.2 Transboundary Diagnostic and SAP elaboration

Using an environmental zoning approach, the Basin countries identified general and site-specific needs and priorities for the conservation, rehabilitation, and preservation of degraded lands; initiated the creation of a shared geographic information system to facilitate dissemination of available physical, biological, social, legal, and economic information; and field-tested specific

[1] The governments of Argentina and Bolivia initiated the BRBB project in 1997 through the Binational Commission for the Development of the Upper Bermejo and Grande de Tarija Rivers Basins (Binational Commission). With the support of the GEF, UNEP, and the General Secretariat of the Organization of American States (OAS), the Binational Commission, conducted the Transboundary Diagnostic Analysis (TDA) that led to the preparation of the SAP.





management mechanisms designed to prevent negative impacts in urban and rural areas, especially as related to land degradation insofar as it affects on the water resources in the region.

Six priority problems for ecosystem-level conservation, rehabilitation, and preservation were identified in the TDA: (1) degradation of soils and intense erosion and desertification processes, (2) scarcity of water resources and limitations on their management, (3) degradation of water quality, (4) habitat and biodiversity losses and deterioration of terrestrial and aquatic biotic resources, (5) losses due to the occurrence of flood-related and other natural disasters, and (6) deterioration of the quality of life of the population living in the Basin and loss of cultural resources. These problems are endemic throughout the Basin, and most are both natural and anthropogenic in origin.

The analysis of their basic and direct causes was the subject of an extensive public consultation process, the results of which defined the strategic actions included in the SAP. As envisioned by Basin stakeholders, the SAP was prepared as a long-term action plan, designed not only to address the root causes of the critical environmental degradation affecting the basin, but also to promote the sustainable development of Basin communities. It is composed of four sets of priority actions: (1) institutional strengthening and implementation of an effective legal and institutional framework for integrated water resources planning and management within the Basin, (2) prevention of environmental degradation, and rehabilitation and protection of degraded environments, (3) sustainable development of natural resources in the Basin, and (4) implementation of a program of consultation, public awareness and participation for environmental protection and management.

3.3 Strategic Action Programme for the Binational Bermejo River Basin

The general objective of the Strategic Action Plan is to promote sustainable development in the binational and inter-jurisdictional basin of the Rio Bermejo, by ⑴ incorporating environmental concerns into the development policies, plans and programs of the various jurisdictions, ⑵ instilling an integrated approach to the basin and the management of its natural resources, ⑶ promoting the establishment of mechanisms for regional articulation and coordination and for public participation and consultation, through ⑷ programs, projects and actions that will ⑸ prevent and resolve environmental degradation and the unsustainable use of natural resources, and ⑹ foster the adoption of sustainable practices in natural resource management.

Strategic Area Ⅰ: Institutional development and strengthening for integrated planning and management of the basin

Is designed to provide a broadly based, participatory institutional framework, likewise developing and strengthening the legal basis underlying the regulation, planning, and environmental and social evaluation, environmental zoning, and economic and financial arrangements that are indispensable for effectively implementing sustainable measures for prevention, restoration, planning, and development of the natural resources identified in the SAP. To this end, special attention is devoted to upgrading and strengthening existing binational and regional entities and thereby establishing forms of organization and inter-jurisdictional capacities suited to carrying out the functions of a basin agency. Also to the development of a holistic regional legislative, economic and environmental framework, by designing, harmonizing and implementing legal and financial instruments concerning standards for water quality management, environmental zoning and land-use regulation in the basin, development of economic instruments for sustainable water use and incorporation of environmental and social costs into project evaluation.

Strategic Area Ⅱ: Environmental prevention, protection and rehabilitation

The strategy calls for strengthening mechanisms of prevention and control of the principal phenomena causing environmental degradation in the basin, as they affect the availability of habitats and biodiversity, the aptitude of natural resources and the quality of water, as well as conflicts resulting from flooding and other disasters. Conservation of nature, prevention and control of erosion and water pollution therefore constitute the strategic focus of this area of action. In this context, it also includes specific actions related to consolidating the system of protected areas in the basin, mitigating the effects of flooding and other natural disasters, and cleaning up watercourses.

Strategic Area Ⅲ: Sustainable development of natural resources

The pressing need to improve living standards for the local population calls for efforts to develop and make sustainable use of natural resources that will give meaning to the institutional development, preventive and remediation measures that are required to ensure those conditions of sustainability, and which are addressed by the other strategic areas. The implementation of projects for the use and exploitation of water resources, which is central to the strategy, is based on three other fundamental aspects that will provide a suitable context for structural development efforts: integrated management of the basin's natural resources, access to and use of sustainable technologies, and research into the management and exploitation of natural resources. In particular, an Integrated Water Management Program for the basin is to be established as a basic planning instrument to guide future activities in the basin, all within a context of strengthening institutions at all levels.

Strategic Area Ⅳ: Public awareness and participation

It embraces activities to identify and coordinate the interests of people and organizations with economic and/or institutional responsibilities in the basin, including the agricultural and industrial private sectors. Access to information is an essential part of the process of encouraging local stakeholders to take an interest in sound management of the basin's natural resources. To this end, a central theme of this component will be to inform the citizenry, including corporate citizens, within the basin through an integrated program of environmental education, institutional transparency, and exchange of information among communities, organizations, and government entities.

3.4 Reservoir planning

Three reservoirs are being planned in the Upper basin of the Bermejo, two of them in the reach which forms the boundary between both countries and the third in Bolivian territory. Their principal objective is to regulate water flows so as to increase minimum flows during the dry season, thereby opening the possibility of irrigation for large areas suitable for agriculture in Bolivia and Argentina. Other objectives include the generation of hydroelectric power, partial flood control and the supply of water for human and industrial consumption. Table 1 provides the main characteristics of said projects. They are intended to act as a major stimulus to the development of the border area, fostering binational integration; in addition, the projects will together help to promote the development process in the Chaco region of Argentina, and southern Bolivia. By regulating the Bermejo River, these projects will basically facilitate agricultural development via the expansion of existing and the incorporation of new irrigation systems.

Table 1　Characteristics of the Binational Projects

Description	Las Pavas	Arrazayal	Cambari
Location			
Site	Las Pavas	Arrazayal	Cambarí
Province (Argentina)	Salta	Salta	---------
Department (Bolivia)	Tarija	Tarija	Tarija
River	Bermejo	Bermejo	Tarija
Priority use of the resource	Energy and Irrigation	Energy and Irrigation	Energy and Irrigation
Dam			
Type	Concrete RCC gravity	Concrete RCC gravity	Concrete RCC gravity
Dam height	105 m	100 m	140 m
Gated spillway	4,500 m^3/s	4,500 m^3/s	4,500 m^3/s
Hydrologic and operational characteristics		555 meters above sea level.	650 meters above sea level.
Maximum operating level	680 meters above sea level.	530 meters above sea level.	615 meters above sea level.
Minimum operating level	656 meters above sea level.	2,776 hm^2	3,800 hm^2
Reservoir area	2,074 hm^2	696 Hm^3	1.675 Hm^3
Reservoir capacity	589 Hm^3	82 m^3/s	86 m m^3/s
Average annual flow	75 m^3/s	6,600 m^3/s	8,000 m^3/s
Project flood level	6,000 m^3/s	4,414 km^2	8,067 km^2
Basin Area	4,050 km^2		
Production characteristics		86 MW	102 MW
Installed capacity	86 MW	423 GWh/a	543 GWh/a
Average annual energy	372 GWh/a		

The reservoirs are located in a natural sensible ecological area subject to erosion processes induced by natural geological instabilities as well as unsustainable land use and deforestation. Development opportunities generated by the projects may intensify the pressure on natural landscape through the expansion of agriculture and forestry, the creation of new settlements and the incorporation of new activities like recreation and tourism. As a consequence there exists a potential for reservoir eutrophication, impairing planned water uses and causing environmental degradation in lake and downstream.

The Strategic Action Programme will be an effective tool to establish a participated managerial framework to improve the planning and decision making process, incorporate effectively the environmental dimension into the dams′ design and operation and promote a regulatory framework to prevent eutrophication risks.

4　Conclusions

Anticipating the construction infrastructure actions for water resources development and utilization, including the proposed reservoirs for low flow augmentation, a Strategic Action Programme has been elaborated for the Binational Basin of the Bermejo River addressing the root causes of environmental problems identified in the basin by the trasboundary diagnostic analysis through of an extensive public consultation process. The SAP, which has been agreed by both countries, the four riparian provinces in Argentina and the riparian Prefecture of Tarija in Bolivia addresses above mentioned strategic key issues necessary to conduct an integrated management of water resources and consequently, prevent and control eutrophication.

The SAP promotes the basin approach; seeks to develop and strengthen the existing binational and regional institutions to install a basin organization, thus setting the grounds for social negotiation; promotes the harmonization and strengthening of the legal framework stressing water and land use regulation of shared water resources and includes the development of an environmental information system, public access to information, environmental awareness, stakeholders coordination through networking and public participation as the basis for implementing truly informed decision processes at project level.

Therefore grounds for sustainable water management, including the fundamentals of eutrophication prevention and control have been set in the region. The GEF and international funding agencies are prone to providing support to start the implementation phase of the SAP. Thus the Bermejo Binational Basin has become a pilot demonstration basin project which may provide useful lessons and inputs to the international community and other shared watersheds in the world.

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System and Methods of Monitoring of Processes of Eutrophication in Lakes and Reservoirs of the South Russian far East

Galina Semykina

Primorskii center for monitoring of environment pollution, Primorskii territorial board on hydrometeorology and environmental monitoring of federal service on hydrometeorology and environmental monitoring of the Russian federation

Now on territory of Primorye Territory there are more than 2000 lakes and 119 reservoirs, including 105 agricultural purposes, remaining household and industrial water-supply. The largest reservoir–Artemovskoe, with full volume 118 Bil. cub. m.

On a mineralization and ionic structure of water of main surface reservoirs as a whole meet the requirements a drinking water-supply. Per the last years in connection with increase of pollution by organic substances sharply increased threat of development in its processes of eutrophication.

Specially authorized RUSSIAN FEDERATION state bodies in the field of environment conservation dealing with monitoring of the environment state and pollution on the territory of the Russian Far East, as well as in other regions include territorial bodies of the RUSSIAN FEDERATION Federal Service on hydrometeorology and monitoring of the environment by the Ministry of Natural Resources.

Observations over environment pollution in the USSR, and in the Primorskii krai, too, were started in the mid-60s.

Pursuant to the order of the Head Department of the Hydrometeorological Service at the USSR Council of Ministers of 24.04.1964 on the basis of a hydrometeorological network there was organized an observation network to control pollution of the atmospheric air, sea waters, land surface waters and radiometric observations. It started functioning in the second half of 1964.

Pursuant to the Resolution of the Central Committee and the Council of Ministers of the USSR No. 898 of 29 December 1972 the State Committee for Hydrometeorology developed a concept and established a State Observations and Control Service operating within the framework of single organizational principles, single programs and methods of measurements.

On 24 November 1993 the RUSSIAN FEDERATION Government and the Council of Ministers issued Resolution No. 1229 on establishment of a Single State System for Ecological Monitoring under which the Federal Service on Hydrometeorology and Monitoring of Environment Pollution of the Russian Federation shall perform the following functions:

- organization of monitoring of the atmosphere, land surface waters, marine environment, soil, circumterrestrial space and complex background monitoring of environment pollution;

- coordination of development and functioning of departmental subsystems for background monitoring of environment pollution;
- keeping a state data base on environment pollution.

For monitoring a condition of surface waters, including reservoirs in Primorskii Kray is Primorskii Center for Monitoring of Environment Pollution (PCMEP) of Primorskii Territorial Board on Hydrometeorology and Environmental Monitoring of Federal Service on Hydrometeorology and Environmental Monitoring of Ministry of Natural Resources of the Russian Federation .

PCMEP has a rather well developed observation network (table 1) and time arrays of observations over principal, but mostly abiotic components of water ecosystems.

Table 1 Programs of a network of environmental pollution monitoring of Primorskgidromet

Environment	Number of points		Observation interval	Controlled parameters
	1990	1997		
Surface waters	46	35	Quarterly Monthly OGF (depending on a program) Seasonally	Gas composition, main ions, biogenes, COD, BOD, phenols, petroleum products, pesticides, SPAV, fluorides, boron, hydrogen sulfide, heavy metals Phyto-zoo-plankton, benthos

At present the observation network on the Far-Eastern ensures regular collection of information on the following parameters:

- Hydroclimatic:

  level, wind waves, currents, temperature, ice situation;
- Hydrochemical:

  for water: pH, alkalinity, oxygen, all forms of phosphorus and nitrogen, silicon, petroleum hydrocarbons (pH), SPAV, chlororganic pesticides (COP) and phosphorous-organic pesticides (POP), heavy metals, phenol, lignite, hydrogen sulfur, mercury, radionuclides;

  for bottom sediments: petroleum hydrocarbons, phenols, heavy metals, SPAV, chlororganic pesticides (COP) and phosphorous-organic pesticides (POP), mercury, radionuclides.

  All measurements are made applying GOST-based methodologies and using devices and equipment approved by GOSTs and verified by Gosstandart (Table 2).

  Data are obtained applying both classical and modern methods:

- gas chromatography,
- nuclear absorption,
- luminescence,
- ionometry, etc.

Table 2 Parameters and methods used in system of national Monitoring of natural waters

No	Parameters	Measurement range	Methods
1		Physical properties	
	temperature	0–50℃	thermometer
	transparency	0–2000 cm	GOST 3551-46 Tests
	Color	0–70 color grades	colorimetry by Pt-Co scale
	Cmell	0–5	organoleptic
	suspended matters	2–50 mg/dm^3	Gravimetric
	pH	4–10	potentiometric
2		Gas composition	
	dissolved oxygen (O_2)	1.0–15.0 mg/dm^3	iodine-metric
	oxygenation	1–100%	Designed
	CO_2		titrimetric, designed
3		Mineral composition	
	Ca^{2+}	1–100 mg/dm^3	Titrimetric
	Mg^{2+}	0–100 mg/dm^3	Designed
	Na^+	1.0–50 mg/dm^3	Titrimetric
	K^+	1.0–50 mg/dm^3	flame-photometric
	Cl^-	2.0–15 mg/dm^3	mercurimetric
	SO_4^{2-}	2.0–50 mg/dm^3	turbidimetric
	HCO_3^-	10–500 mg/dm^3	potentiometric titration
	hardness	0.5–8 $mmol/dm^3$	Titrimetric
	general mineralization	50–7000 mg/dm^3	Designed
4		Biogenic elements	
	phosphates	0.01–0.2 mgR/dm^3	spectrophotometric
	nitrite nitrogen	0.01–0.3 mg/dm^3	spectrophotometric
	nitrate nitrogen	0.01–0.3 mg/dm^3	spectrophotometric
	ammonium nitrogen	0.3–4.00 mg/dm^3	spectrophotometric
	Silicon	0.1–2.0 mg/dm^3	spectrophotometric
	Ferrum	0.05–1.00 mg/dm^3	spectrophotometric
5		Pollutants of organic origin	
	BOD_5	1.0–11 mgO_2/dm^3	iodine-metric
	COD	4.0–80 mgO_2/dm^3	dichromate oxidation
	phenols	1.0–25 mg/dm^3	extraction-photometric
	oil products	0.05–1.0 mg/dm^3	infrared- spectrophotometric
	SAS anion	0.015–0.250 mg/dm^3	extraction-photometric
	DDT	0.02–0.2 mg/dm^3	gas chromatography
	DDT	0.01–0.3 mg/dm^3	gas chromatography
	DDE	0.005–0.15 mg/dm^3	gas chromatography
	α-HCCH	2.0–50 $\mu g/dm^3$	gas chromatography
	β-HCCH	2.0–50 $\mu g/dm^3$	gas chromatography
	propanid	1.0–30 mg/dm^3	gas chromatography
	Ordram	4.0–100 mg/dm^3	gas chromatography
6		Heavy metals	

No	Parameters	Measurement range	Methods
	Cu	2.0–100 mg/dm^3	spectrographic
	Ni	2.0–100 mg/dm^3	spectrographic
	Pb	2.0–100 mg/dm^3	atomic absorptive
	V	2.0–100 mg/dm^3	spectrographic
	Mo	2.0–100 mg/dm^3	spectrographic
	Co	2.0–100 mg/dm^3	spectrographic
	Mn	2.0–100 mg/dm^3	spectrographic

By background hydrochemical composition the waters of the lake basin and its rivers are referred to the Far Eastern type, which is characterized by small temporary amplitude of quantity fluctuations of dissolved salts and by absence of obvious relation between debits (levels) and mineralization, not high as a whole. The magnitude of the lake water mineralization changes within 60 –120 mg/dm^3

Waters of the lakes and reservoirs belong to the carbonate–calcium type.

pH index of the lakes and reservoirs waters changes within small interval: 7.4 –7.6 pH in summer period and slightly decreases in winter period till 7.0 –7.2.

Practically all rivers in Russian Far East are polluted to this or that degree, but by salinity and ion composition they meet, largely, the requirements of drinking water supply, except for several rivers in the north and east of the Peter the Great Gulf, and rivers in major ore mining regions in the center of the Primorskyi krai. Here run-off rates are in general, much higher than in other basins of Russian rivers and range from 30 to 50 t/sq. km a year.

For instance, according to estimates a specific annual disposal of polluted waste waters per one urban citizen in the Primorskyi krai in late 1980s–early 1990s averaged to 183 cu. m/man, that is nearly 30 % higher than the Far East average.

In agricultural regions the sources of water pollution include water percolated from the fields that were treated with chemicals and fertilizers (first of all, from irrigated fields) and waste waters from animal farms (middle reaches of the Razdolnaya River, a basin of the Tumen River). The main cause of surface water pollution is low efficiency of wastewater treatment facilities (an average figure for the Primorskyi krai is not more than 15 %).

The main problem in status of surface waters of the Russian Far East is their pollution by biogenic substances. Lake Eutrophication is determined by content of biogenic elements.

Lake may be seen as a Mirror Reflected Civilization Level of Mankind–Talking about Strengthen Lake Management

Liu Shukun
China Institute of Water Resources and Hydropower Research, Beijing China

Abstract Lake can be seen as a mirror reflected the civilization level of mankind lived in watershed. According to lake situation the civilization level of mankind lived in the watershed should be shined upon. Rapid deterioration of water quality of lake is inevitable outcome owing to no civilization style of living and producing of residents lived in there. In order to improve lake situation the lake management must be strengthen included in the management of mankind activity in watershed. If only civilization level of mankind lived in watershed was enhanced, the lake management would have hope.

Key-words Lake Watershed management

Lakes are equal to large-scale natural reservoirs, collecting and regulating inflow from watersheds. Therefore the region around lakeside is quite fit mankind to live. There are sky and water appearing same color, beautiful panorama in the region. There are gentle breezes blowing and blowing, pleasantly cool and delightful for mankind living in the region. There are wild duck, chestnut, lotus root, full fish and rice in the region. These eulogize words fully express that lakes have important position and are great role in mankind life, included in flood control, water supply, regulate weather, landscape, ecosystem etc. Having benefit of lakes, a lot of general mankind civilization, a number of developed big cites, and many economic regions emerged early around lakeside.

At the same time, any kind of activity of mankind society must yet influence lakes. Following confluence process from watershed to lakes, a large number of information substances from activity of mankind society will together sink inflow to lakes. It included in that:

⑴Life information. Discharge and disposal of mankind life, such as excreta, sewage, detergent, domestic refuse and treatment way of that etc.

⑵Cultural information. Every kind of mankind activity in travel and entertainment, special those activity which progress at water surface and lakeside, such as play water, rowing, angle and accompany service facilities etc.

⑶Production information of farming and animal husbandry. It included cattle waste and matter runoff from agricultural production. The quantity of water and soil runoff, pesticide, and chemical fertilizer in process of agricultural production is closely related with the cultivation method.

⑷Production information of industry. It included discharge and proposal from every kind of process of industrial production and treatment technology for these wastewater and waste residue , special poison and harmful matter in these matters.

When these information matter inflow to lakes will lead to variation of water quality and ecosystem of lakes. This kind of variation is not equal to natural slowly variation process of water quality and ecosystem of lakes. The speed of this variation is very fast, so that can destroy lakes in a few or ten years.

- Mankind profited from lakes, and injured to lakes, at final itself eats the evil consequence. Mankind should lived harmonious with lakes together. Yet lakes may be seen as bright mirrors. It can reflect either civilization or ignorant of mankind lived in watershed.

1 Water Resource Protect and Sustained Develop of Lake

In order to radically solve the problem of water resources protect must persist in principle of sustained develop. This is the main principle of civilization produce and life of mankind lived in watershed. The sustained develop principle insist on accomplishing harmonious develop of population, economy, environment and ecosystem in watershed. It insist also on according to support capacity of resources, environment and ecosystem to work out the develop plan of population and economy.

- Lakes have important resources function, environment function and ecological function in watershed. The continuous worsen of lake water quality will step by step lead to lose above-mentioned three kinds of function. Finally will lead to harming sustained develop of watershed.

The theory of sustained develop claims fair between generations. The mankind of present age must all out protect these functions of lake, control the aging speed of lake, so that the mankind of next age would also fully shared benefits of lakes. At the same time, the sustained develop theory claims fair between regions. The residents lived in watershed must equality share rights to utilize resources of lake, and corresponding must equality undertake duty to protect lake resources. It would violated principle of sustained develop that to do some thing only interested for partial and local zone, but damaged benefits of another region,.

In order to accomplishing sustained develop of society in watershed:

- Whole residents in watershed must join to bear responsibility to protect lakes.
- The mankind activity in watershed must not quicken the natural aging progress of lakes.

Because of mankind activity leading to eutrophication of lakes can be seen a warning signal. It is explained that the sign of no sustained develop already appeared in the watershed. And the same time it also is the sign explaining serious worsen of resources, environment and ecosystem in the watershed. Must in time to regulate the style of life and produce of population of the watershed, to strong lakes management, to solve the eutrophication problem of lakes according to require of sustained develop of whole watershed.

- The lake eutrophication is caused by bad mode of life and no cleaning style of produce of mankind in watershed. Therefore to radically solve the eutrophication problem of lakes must use management measures, and must lead residents step by step to use cleaning style of life and produce.

2 Lake Management

The objective of lake management is improving water resources, water environment and water ecological condition of lakes. Lake management is included three parts, which are watershed management, water body management and lake-basin management.

2.1 Watershed management

The important point of watershed management of lakes is to control pollution source, to decrease pollution load from inflow of lakes.

(1)Management of draining sewage from factories and mines enterprises, and large-scale tourism facilities.

(2)Management of domestic sewage from cities and towns.

(3)Management of sludge on riverbed and municipal refuses.

(4)Management of excrements of human and cattle in county.

(5)Management of technology using pesticides and fertilizations.

(6)Management of using detergents.

(7)To control soil and water loss in watershed.

(8)Management of water body and wetland in watershed.

Besides proceeding treatment in workshop for every kind of pollution sources, must also developed family treatment (such as farm manure, marsh gas pool and etc), soil treatment, wetland organism treatment, pebble trough on riverbed and etc.

- Watershed management besides the management proceeding by professional contingent need develop volunteer’s troops. Through spreading scientific knowledge about environment protect and publicizing relative laws set up the consciousness of residents in watershed to protect lakes.

2.2 Water body management

The key point of water body management of lakes is to control water quantity, water quality and ecosystem of lakes for maintaining normal function of lakes.

(1)Dispatching management of water quantity and water level of lakes.

(2)Monitoring management of water quality of lakes.

(3)Investigation of lakes ecosystem and repairing management.

(4)Fishery management of lakes.

(5)Water transportation management of lakes.

(6)Tourism and entertainment management on water surface of lakes.

- The water level management must be emphatically research because lakes water level greatly effect the ecosystem of lakes. Addition fishery, water transportation and tourism on lakes water surface also directly cause pollution of lakes, so the management for that must reinforce. But the most important matter is investigation and monitoring for water quality and ecosystem of lakes. The best way is creating auto-monitoring system to water quality for servicing management decision.

2.3 Lake basin management

Lake basin management is point to manage lake basin topography and sediment for controlling water quality of lakes avoided influence coming from bed silt released.

⑴Lakeside region management.

⑵Investigation and dredging for bed silt of lakes.

⑶Management for bed silt to be coverage.

- Lakeside region management greatly influences for water quality and ecosystem of lakes. The lakeside region is transient zone of water surface with land adjacent of lakes, also transient belt of aquatic organism and terrestrial biosphyre. There are plentiful amphibians, small animals and aquatic birds staying in the region. At the same time there is also becoming protect region of water quality of lakes. There is important barriers because of intercepting and observing pollution coming from surface source. But when built bank around lakeside, the lakeside region would been damaged. Therefore when building the bank must be meanwhile pay attention to repair the lakeside region.

3 To establish Modernized Management System of Lakes

In order to do good lakes management must step by step establish modernized management system of lakes, it included four parts as follow.

3.1 Information management system of lakes

This part included geographical information, information of land, population, economic, environment, ecosystem and etc in watershed. Specially, the pollution source information must be collected and controlled in time.

Collecting and controlling in time for information about water level, discharge of inflow and outflow, situation of water quality, capacity and ecological regime, fishery, water transform, tourism and etc.

Collecting and controlling for information about distribution bed silt of lakes, and pollutant content and released situation of that.

3.2 Management system of lakes plan

Management of lakes plan must obey the principle of sustained developing. Either formulating ecological, plan and goal of environment protect, or control target of pollution source in the watershed must progress under the guidance of the principle of sustained developing.

Based on the plan of watershed to formulate water resources protect and ecological repairing plan of lakes.

The goals of above mentioned plans must also be as the goals of management work of lakes and watershed.

3.3 Dispatch and management system for key project

This part included control operation situation of hydraulic projects and treatment works of pollution discharged. Based on the condition of hydrologic and water quality in lake watersheds with society need for flood control and water supply to build reasonable dispatching scheme.

3.4 Forecast and forewarn system on water quality of lakes

To build forecast model on water quality of lakes, and based on the operation situation of key projects could been forecast the water quality of lakes in future. To build relevant forewarn system, when the water quality of lakes appear abnormal variations in forecast or real test and may be damage the crowd health, must publish the warn to corresponding region in time.

The lake management system, which consist of above-mentioned four parts, can utilize the technology of modernized computer network, communication, GIS, GPS, RS and etc. That can become interconnection system in management range of lake watershed, and put into practice science management for lake and it's watershed.

4 Conclusion

Lake entrophication is phenomena of lakes aging. And lakes appearing entrophication in short time is the consequence owing to harmful activity of mankind. For these lakes any single control measure do not prove effective. Only using all kinds of methods to carry out comprehensive treatment can be improve the situation of ecology and environment of lakes. In this methods to change the harmful style of produce and life is the most important, the most efficacious, but also the most difficult.

Attach Importance To Lake With Macrophyte Responding Eutrophication Problem

Li Yawei[1], Bjoern. Faafeng[2], and Jonas Fejes[3]

1) Inner Mongolia Environmental Sciences Institute, Huhhot, China

2) Norwegian Institute For Water Research (NIVA), Oslo, Norway)

3) Swedish Environmental Research Institute (IVL), Stockholm, Sweden

Abstract Lake Wuliangsuhai is situated in the Grassland and semi-desert landscape of autonomous region of Inner Mongolia, P. P. China. The lake is large (300m^2) and shallow (dmax 2.5m) and most of it's surface is covered by reed swamp and submerged vegetation. The lake is an important site for water fowl, both resident and migrant. The lake is badly polluted by nutrients, dissolved organic matter, particles and mineral salts. To improve the water Quality, increase the biodiversity and stop the reed belt from further expanding, a comprehensive R&D project was initiated between Chinese, Norwegian and Swedish researchers. Preliminary results will be presented.

Key-words Lake Eutrophication Macrophyte Responding

Considering getting more and more rich in nutrients, a water body is filled with a great deal Phytoplankton and Macrophytes, leading to eutrophication. If Phytoplankton increases quickly, it is called algae type eutrophication, if Macrophytes grows superfluously, it is called plant type eutrophication. It is considered intergradation that mixing Phytoplankton and Macrophytes. Plant type eutrophication lakes occur generally in shallow lakes (water depth less than 4m). A lot of lakes in China are located in shallow catchment, and nutrients content in them already exceed eutrophication control alertness range greatly. So researching and controlling eutrophication, we should pay more attention to grass type eutrophication lakes. The article takes Lake Wuliangsuhai in Inner Mongolia Autonomous Region as an example to narrate that harm of grassy type eutrophication and importance and necessary of treatment and control.

1 Entironment of Lake Wuliangsuhai

Lake Wuliangsuhai is situated in Urad Front Banner of the Bayannaoer Prefecture of Inner Mongolia Autonomous Region. It is linked to Hetao Irrigation Catchment in the west, to Wula Mountains in the east, and located at the east tip of the Hetao Plain.

The lake is 35–40km long (N-S) and 5–10km wide (E-W), with an area of about 293km^2. The average elevation of the lake over the years is 1,018.5m, the capacity is 2.5–3$\times 10^8$m^3. The maximum depth is about 4m, the average depth is 0.7m, but most part is at 0.5–1.0m.

Annual average temperature is 7.3℃, annual sunshine 3,184.5h, average annual rainfall

224mm, average annual evaporation 1,502mm. The annual number of frost-free days is around 152. The lake begins to freeze in early November, and the freezing period lasts 5 months.

Lake Wuliangsuhai is an important part of Hetao agriculture irrigation and drainage system. Yellow River is only one irrigation water resource of this area. Sanshenggong branch dam is the intake of Yellow River. About 6.0 billion m^3/a water passes through the areas. There area 6,900 km^2 plowland in the irrigation areas, and it is planed to add to 7,300 km^2.There is a main irrigation channel and about 20,000 branch irrigation channels composed as a irrigation system in Hetao areas. Drainage system consists of 22,000 branch drainage channels which head for the main drainage channel together into Lake Wuliangsuhai. These pumping stations lift 0.7–0.9 billion m^3 water from drainage channel to Lake Wuliangsuhai. The surface runoff flux of the lake is 0.1 billion m^3 each year, other supplement about 1 billion m^3 each year. Once the surface level of the lake is higher than the sea level 1,018m, or in the low water period of Yellow River, Lake wuliangsuhai will drain to supply Yellow River. The output is about 2 billion m^3 every year, namely the lake supply 20 m^3/s water to the Yellow River. The lake changes water every 160–200 d. See the following figures:

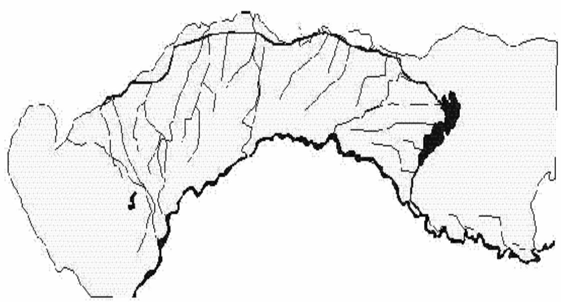

Fig. 1 The drainage system in the Hetao area

2 The Importance of the Lake

According to the existing functions of the lake, the lake play the important role in following sides:

（1）the Only One Acceptable Body and Drainage Path in Hetao Irrigation Areas

（2）the Water Resource Supplement Reservoir in Low Water Period of Yellow River

Lake Wuliangsuhai supplies 2×10^8 m^3water to Yellow River in low water period, namely the lake supply 20 m^3/s water, which is 20% of the average flux of Yellow River.

（3）Important Reed Production Base in Local Areas

The reed yield is about 1×10^5t/a presently，which is the main material base in local paper factories.

（4）Important Site of Birds Habitat and Migration

There are a lot of reed and grass in the lake. The wetland provides a good habitat and abundant food for birds. There are 16 orders, 45 families, 103 species in recorder, of which, migratory birds 67 species, resident birds 30 species, including state No.1 grade protection birds 5 species, which are *Ciconia nigra, haliaeetus leucoryphys, haliaeetus albiilla, Otis tarda,* and *Larus relictus Lonnberg*; No.2 grade protection birds are 25 species such as *Pelecanus philip pensis Gmelin* and *Cygnus clor*。Lake Wuliangsuhai is located in middle part of Eurasia.

（5） Important Sites of Local Fishing and Tourism

（6）the Function of Adjusting Micro Climate of the Local Areas

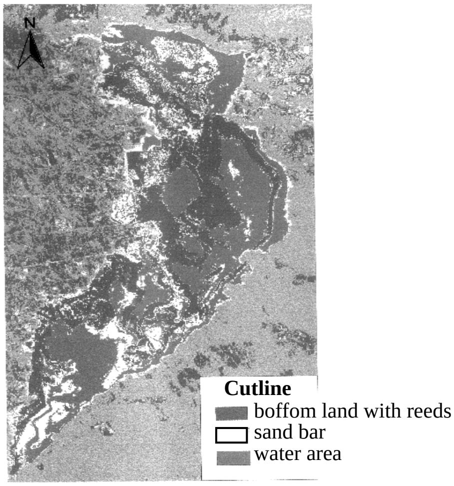

Fig. 2 Distribwtion of ecotype in Lake Wuliangsuhai

3 The Chief Environmental Problems of the Lake

3.1 Worsening water quality

Water quality gets worsening more and more, manifesting such three sides:

（1）The concentration of nutrient salt is higher,

（2）Organic pollution is more serious, and

（3）Mineralization and salinity are increasing.

We can find nutrients and organic compound pollution have increased over once in recent 10 years through the following table.

The Monitoring Results of Water quality of Lake Wuliangsuhai

Sapling sites	Time (a)	NH_4-N (mg/L)	T-N (mg/L)	T-P (mg/L)	COD (mg/L)	BOD_5 (mg/L)	Salinity (mg/L)
the inlet of the lake	1988	3.12	1.89	0.128	11.75	1.73	1160
	1999	1.81	3.21	0.252	60.0	2.8	
the center of the lake	1988	1.345	1.78	0.0677	14.08	1.86	1380
	1999	0.56	1.59	0.168	55.1	2.96	
the outlet of the lake	1988	0.618	1.58	0.077	17.5	1.70	1628
	1999	0.63	1.67	0.116	69.3	2.83	2139

3.2 Reed overspreading

In recent 10 years, the reed yield of the lake has increased form 60 thousand tons to 100 thousand tons, adding 67%. But the lake hasn't take any measures to raise yield of per unit area, obviously the reed areas in the lake is the main reason why the yield increased.

3.3 Grass growing quickly

The half area of Lake Wuliangsuhai is reed belt; the other is almost filled with submerged vegetation. From May to the early November every year, submerged vegetation grow excessively， forming thickly submerge grassland. Maximum productivity of submerged vegetation is 12.0 kg/m^2 (fresh weight), average is 0.568 kg/m^2 (wet weight). Submerged vegetation biomass can be 640 thousand tons (fresh weight).

3.4 Odoriferous water and dead Fish

In recent years, the residents are already used to black and odoriferous water in the lake. Fish are dead in the beginning of spring generally.

During the monitoring in 1999, there are many dead fish and dead shrimp after opening 0.5m ice layer in most monitoring stations. The maximum dead fish is 2.5kg. When ice layers open, smells give off.

3.5 Mud and sand ramming

Flood brings a lot of mud and sand, besides the lake bottom is filled and leveled up by being bodies. The flood of 1997 fill mud and sand into the lake about 1km。

3.6 Black and odoriferous sediment

Lake Wuliangsuhai accepts a lot of water from irrigation areas each year. It accelerates the bottom level that a large quantity of suspended solid in the irrigation water and emerging and perishing merged and submerged vegetation. The bottom level adds about 1cm annually, forming 0.2–0.5m sediment， which is odoriferous, black, and particles are thin. Organic matter content of the upper layer of the sediment is 3.02%–5.28%.

3.7 Water Resources Crisis

Due to implementing flooding irrigation in the farmland, and no water in lower reaches of Yellow River in low-water-period, when saving engineering is commencing in Hetao Irrigation areas, the input value of whole irrigation areas will decrease from 5.2 billion m^3 to 4.0 billion m^3， which reduce 23％. According to the results of Environmental Impact Assessment of the Saving Engineering，the input of 2005 and 2015 will be cut down to 4.5 billion m^3 and 3.9 billion m^3 respectively, 73% and 43% of existing input. It suggested supplying at least 4billionm^3 water into the lake.

4 Characteristic of Typical Plant Type Eutrophication

Main characteristics of plant type eutrophication are high concentration of nutrients, and macrophytes overgrowing. The author has provided 8 indicators to assess main characteristic of Lake Wuliangsuhai as a plant type eutrophication lake. In fact, as to shallow lakes, when T-N and T-P are 1 and 0.03 mg/L, and macrophytes is chief advantage category, covering more than 70%，macrophytes biomass exceeding 1.2 kg/m^2，there will be a trend of grassy type eutrophication. Especially, when plant type eutrophication lakes is in vegetation growing season, due to vegetation's enormous capability of holding up suspending solid absorbing nutrients, and filtrating toxic matter, the transparence of water body is good. But it is not be ignored that macrophytes often interfere fishing and sailing, and accelerate lakes filling up and changing into swamp. Cankered macrophytes in not growing season effects the water quality severely.

5 Discussion

There are shallow lakes all over China, the important shape characteristic is convenient for macrophytes growing and multiplying in lake zoology community facies. Namely, once these lakes are polluted by nutrients, there are trend and possibility of plant type eutrophication taking place. So the situation should be paid more attention, and try to find treatment measures as soon as possible. If adopting artificial controlling measures, the worse condition can be postponed, but it is very difficult to control. Such reversible ecological process should be research on ecological system balance and keeping ecological system sustainable development.

As to the Lake Wuliangsuhai, we have made a lot of research for more than fifteen years, but many background of the lake are still not known such as the loading of pollution content especially coming from agriculture and what would happen in the lake after harvesting submerged vegetation. We hope to get help from other experts in the same field.

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Comprehensive Strategy and Practices on Lake Eutrophication Prevention and Treatment

Tu Qingying[1], Zhang Xinbao[2], Zhuxuan[3], and Zhang Yongtai[4]

1) Nanjing Institute of Geography and Lake Research under Chinese Academy of Science, Nanjing, 210008

2) Chengdu Institute of Mountain Disaster and Environment under Water Conservancy Ministry of Chinese Academy of Science, Chengdu, 710054

3) Tianjing Municipal Institute of Environmental Science, Tianjing, 300191

4) Shanghai Fuxinaijian River Improvement Co., Ltd, Shanghai, 200031

Abstract Lake and its catchment is an integral ecological system. The ideology of overall pollution control is that, based on different ecological regions and pollutant types, applying ecological restoration technology, biological purification technology, physical pollution-removal technology, artificial regulation technology and various engineering technologies, to conduct comprehensive treatment so as to prevent soil from going downhill, slope from being exposed with soil, nutrients from flowing into lake. The long-acting follow-up management and operation pattern is the guaranty of persistent effects of environmental treatment projects.

Key-words Ecological region Overall control Long-acting management

1 Prevention against Lake Eutrophication is the Major Issue of Present Lake Treatment

The occurrence and development of Chinese lake and reservoir eutrophication started mainly in the beginning of 1970s. While survey on eutrophication of major lakes and reservoirs was conducted in the beginning of 1980s, the lakes in eutrophication status or in super eutrophication status were mainly smaller city lakes located in or near large and medium cities, such sightseeing lakes as Xuanwu Lake in Nanjing, Gantan Lake in Jiujian, Moshui Lake in Wuhan, Xihu Lake in Hangzhou etc.. They were first highly affected by industrial waste water, domestic waste water and human activities from tourism ect., and so to be the first to go into eutrophication and super eutrophication type.

On the Over the past 20 years, lake and reservoir eutrophication in our country has again experienced a swift and violent development. Eutrophication has spread all over to various lakes and reservoirs in the country; Many large lakes and reservoirs, such as Chaohu Lake, Dianchi Lake, Taihu Lake, Yiqiao Reservoir etc., have reached super eutrophic or eutrophic stage. Such lakes are mostly the drinking water sources for city residents along them. Due to deterioration of water quality, precious but limited fresh water resource lost its utilization value, which seriously affects the production and life of people nearby, and restrains the development of regional economy.

Whole, the shortage of water resources, degradation of water environment and pollution of water quality have become major issues that affect national economy and the people's livelihood. Among them, the development speed and seriousness of lake water eutrophication are enough to surprise people at home and aboard. Prevention against lake eutrophication is a matter of great urgency, and is actually the major subject matter of lake pollution treatment in our county.

2 Engineering Design for Overall Control of Lake and its Catchment Pollution

In larger lakes near cities of our county, such as Dianchi Lake in Kunming, Zhaohu Lake in Hefei etc., 50% of total N and P loads into lakes are from city waste water, and the other 50% are from non-point-source surface runoff and rainfall in lake region; In lake and reservoir which are far away from city or less affected by city industrial waste water and domestic waste water discharge, such as Yiqiao Reservoir, Gaozhou Reservoir, Dingshang Lake, Nanshi Lake etc., nutrient loads are mainly from non-point-source pollution of lake catchment, with N and P loads accounting for 60%–70% of total loads into lakes, among which, agricultural runoff is taken as the dominant factor.

These nutrients are major reason for lake eutrophication. Hence, non-point-source pollution control and "algae inhibition" in watershed are important respects of prevention against lake eutrophication at present.

Our principal ideology about overall control of lake and catchment environmental pollution is, taking environmental system science and ecological principle as basic guiding theory of pollution control, and regarding lake and its catchment as an integral ecosystem. Based on different ecological regions and pollution types, various kinds of technologies are applied to conduct control, interception, transformation and treatment. The aim required to achieve is to prevent soil from going downhill, slope from being exposed with soil, nutrients from flowing into lake and water from being polluted.

As to environmental treatment technologies, ecological restoration technology, biological purification technology, physical pollution-removal technology and artificial regulation technology are taken as dominant factors, meanwhile, necessary engineering technology is applied so as to conduct overall and comprehensive treatment.

Firstly, taking functional divisions of whole catchment's ecological environment as background, based on different geomorphologic locations and environmental problems, ecological region is divided. The first-level ecological region is generally divided into the following five types (see figure 1):

⑴ecological division of upland forestry

⑵ecological division of plain agriculture

⑶ecological division of wetland

⑷ecological division of lake shore

⑸ecological division of lake water

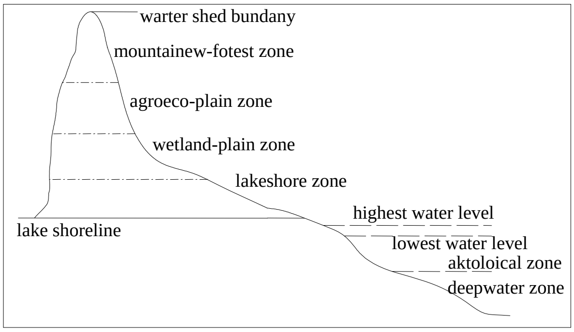


Fig .1 zone dividing of the lake basin

The second-level and the third-level regions can be divided according to the types of its species and function of ecological region.

Secondly, the design of pollution control engineering could be made according to environmental problems and present pollution situation of different ecological regions(see figure 2).

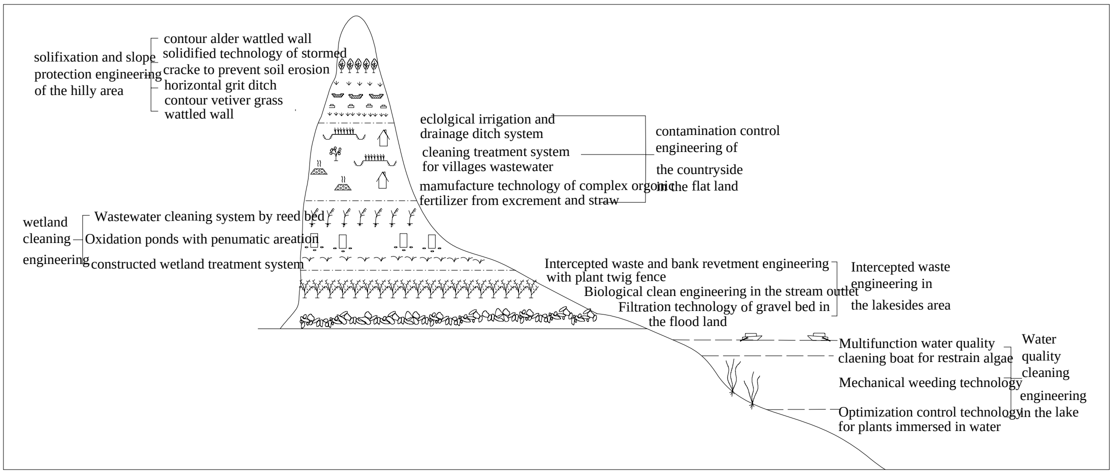


Fig. 2 Contanination controlengineering of the lake basin

2.1 Ecological division of upland forestry

Taking control of sediment pouring and surface runoff as major aims, and taking water-holding engineering and biological engineering as major technical means, to conduct soil fixation and slope stabilization of upland and ecological restoration engineering as well. In the project identification proposal about Yilong lake in Shiping county, Honghe prefecture of Yunnan, we designed the following activities in details:

⑴along contour, with average interval of 50 meters, to conduct biological engineering by building plant fence with Xinyin Silk tree, 2.8km, to prevent cultivated land on slope from surface erosion.

⑵to apply such engineering technologies as grouting rubble check dam and planting

Sweet bamboo as ditch bottom forest, so as to prevent ditch from erosion.

⑶to protect slope with Vetiver grass, Baixi grass(500 meters) and to cover rock-exposed slope surface with liane (20 mu).

In the preliminary design of adjacent pollution treatment of 《*Water Source Conservation Engineering of Yiqiao Reservoir*》, we made the following engineering designs as grouting and placing rubble check dam (630 ones), heightening and strengthening ridges of terraced field (8.01 million mu), building plant fence for ditch protection (691.0km). It is expected that flood detention capacity of terraced field will increase by 5 million m^3, pollution loads into river from agricultural field and villages on the sides of ditch channels will decrease by 30%, and sediment loss will decrease by 50%. In engineering region on trial, sediment loss is predicted to reduce by 70%.

2.2 Pollution control engineering in plain villages[1]

The major pollutants of rural villages, orchards and farming area are domestic waste water, solid wastes, crop residual, human being and animal manure etc.. In the preliminary design of adjacent pollution treatment of《*Water Source Conservation Engineering of Yiqiao Reservoir*》, we introduced high technology and ripe patent technology to dispose solid wastes, crop residual, reed, water hyacinthes, human being and animal manure, and to conduct centralized disinfection, sterlization, deodoration, drying and crushing, microbial fermentation, decomposition and transformation.

Preparations will be made to establish a high-efficiency compound fertilizer plant of proper size at proper site,

meanwhile collection system and operation pattern using wastes to substitute fertilizer will be set up.

Village pollution discharge and purification engineering are composed of round-the-lake interception ditch and system of road, ditch, channel and pool so as to treat village waste water. Ditch size takes the flow of agricultural field and village surface runoff as design standard. Meanwhile, plant fence combined with arbor, shrub and grass will be built so as to play a role of flood detention, wastes reception, purification and beautification.

2.3 Biological purification engineering in wetland

In Yilong Lake of Yunnan and Zhouzuang in Kunshang of Jiangshu province, we designed and constructed artificial wetland system for waste water treatment. The artificial wetland for non-point-source pollution control of Yilong Lake takes the following as major treatment target, i.e. village and township waste water, waste water from bean products production, agricultural runoff and effluent after secondary treatment in county waste water plant, which contains high concentration of COD_{Cr}, TN, TP. Zhouzuang artificial wetland takes city domestic waste water and

[1] ecological position—refers to species' position and function in ecosystem.
ecological region—refers to geographical location of biocommunity.

waste washing waste from food and beverage industry as major treatment target.

The major constructions of wetland engineering for non-point-source pollution control include:

- water delivery system: ditch and channel, pipeline etc.
- pre-treatment system: aeration and grit settling tank, sedimentation tank etc.
- artificial wetland treatment system: water distribution, various kinds of treatment bed, water retaining dam (dike), construction and restoration of emergent aquatic plant etc.
- effluent collection system: underground drainage pipeline, undercurrent-type surface drainage device, construction of biological pool at drainage outlet etc.

Generally, effluent water quality is:

COD_{Cr}	removal rate ⩾90%
BOD_5	removal rate ⩾90%
T-N	removal rate ⩾85%
T-P	removal rate ⩾90%–95%
SS	removal rate ⩾80%

Construction investment equals 1/3 of that of second-level waste water plant of the same size which uses denitrification and dephosphorization method.

2.4 Wastes interception engineering of lake shore

Coastal area along lake shore line is ecological protection belt of lake. Land-and-water staggering belt between high water level and low water level is specially the region of biodiversity protection. Submergent plant belt in shallow area is also the important site for fish habitation, oviposition, growth and multiplying. Hence, ecological protection of lake shore area is very important.

In the preliminary design of adjacent pollution treatment of 《*Water Source Conservation Engineering of Yiqiao Reservoir*》, our major designs are round-the-lake wastes interception ditch, and to build arbor and shrub plant fence with whole length of 74km.

2.5 Water quality purification engineering of lake (reservoir)

Prevention technology of lake (reservoir) eutrophication is a frontal issue of present treatment technology. In the preliminary design of adjacent pollution treatment of 《*Water Source Conservation Engineering of Yiqiao Reservoir*》, we applied 3 technologies:

- algae inhibition technology using multiple-function water quality purification ship;
- mechanical grass-removal technology;
- optimization and regulation technology of submergent plant.

As for super eutrophic lake (reservoir) which has formed "algae bloom", Microcystis aeruginosa-concentrated layer is first required to be destroyed in order to inhibit occurrence of "algae bloom". Mechanical physical technology for algae removal and inhibition is one of the most safe and reliable methods. FOXIN multiple-function water quality purification ship has kinetic energy for high-speed oxygenation and air aeration, it can destroy Microcystis aeruginosa -concentrated layer effectively, and can complement dissolved oxygen to space of various water depth so as to change the extremely unbalanced situation of vertical distribution of dissolved oxygen in water, meanwhile, to improve transparency of lake water quickly, to enable photosynthesis of bottom hydrophyte to go on successfully, and to improve growth environment of bottom aquatic animal, so as to create favorable condition for restoration of aquatic ecosystem.

3 To Establish New Pattern with Pollution Treatment and Economical Development in Harmony and New Mechanism on Long-acting Follow-up Management and Operation

Huge funds and effective technology required in lake pollution treatment are important factors which nag and restrain our progress.

We believe that, this new pattern on lake treatment and new operation mechanism are able to motivate various investors, and it is a road for ecological environment protection which is in accordance with Chinese situation, and is economically effective,realistic and feasible.

Expert group composed of some scientists from relative institute under Chinese Academy of Science set up companies together with Shanghai Fuxinaijian River Improvement Limited Company and other enterprises. They make efforts to explore a road of socialized lake treatment investment, interated treatment engineering, serialized application technology, industrialized environmental protection work. Applying economics theory and environmental system science, they seek the combined point of environmental treatment technology and economics construction for lake and its catchment, and effectively combine treatment and improvement of ecological environment with development and utilization of biological resources in order to attain the aim of continuous improvement of ecological environment, efficient and sustainable development of lake region economics.

They also establish a multivariate investment mechanism involved with enterprise capital, government investment, high-technology investment from institute, and farmers as well, and creat a totally new operation pattern of “base+peasant household+company+high techology+market”.

As a result, scientific and technical personnel can use high technology to set up powerful technical guaranty system for clean and efficient ecological agriculture, and conduct pollution prevention monitoring for the whole procedure of agricultural production and overall management on rural environmental quality, also establish extensive green food base and ecological village (see figure 3); Local government and farmers can combine lake treatment effectively with development of wealth acquiring programme of locally-unique economics, therefore, output value of the present low-value agricultural field in lake catchment will increase several times over, and farmers will get rid of poverty and become wealthy steadily;

Meanwhile, by making full use of advantages of enterprise participation and through company operation, necessary social funds will be collected and used for ecological engineering of lake treatment and for establishment of green food base. At the same time, by making use of company's market-promotion system, subsidiary agricultural products from ecological agriculture production will be pushed into wide market, which creates strong blood-forming function for environmental protection itself, and makes environmental treatment activity head toward continuous benign cycle;

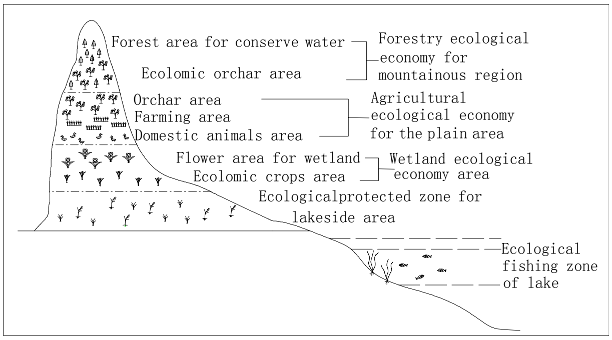


Fig. 3 Ecological economic structure of the lake basin

Government's investment on environmental protection and lake treatment will have the possibility of inflation proof and value rising, and in the earlier phase of treatment, after nonrecurring input, government won't have to bear heavy operation expenses year after year.

Our operation pattern in details is :

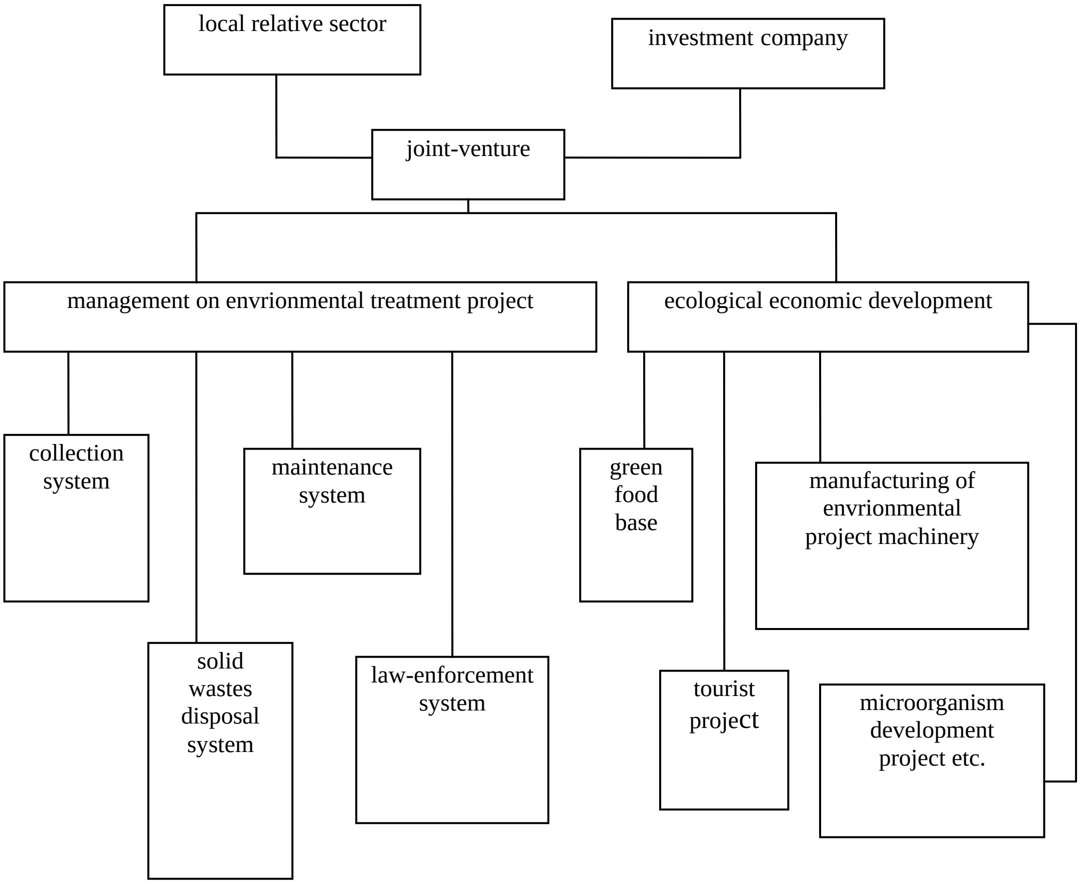
⑴In the project identification proposal of demonstration program for pollution treatment and economics construction of Yilong lake in Honghe prefecture of Yunnan, based on locally favorable climate and rich biological resources, and based on the require that non-point-source pollution be controlled to prevent soil from going downhill, slope from being exposed with soil, nutrients from flowing into lake.

In seriously-eroded region after 1,600 meter of Yilong lake catchment, we selected and designed two forest-and-herb combined ecological economic forest bases (Kunyang barren mountain with limestone in it, arid slope-land with pine trees on it) as treatment program on trial. We use "orange forest+Dioscorea" as pattern of stereoscopic forest-and-herb combined ecological forest, and protect slope by building plant fence withXinyin Silk tree and by planting Vetiver, Baixi grass so as to increase the value of present low-value and non-value cultivated land on slope, to keep the output value per mu not less than 3,000 yuan, to reduce soil erosion index from 1,000–5,000 t/km^2 • a to 500 t/km^2 • a.

A factory of 18,000m^2 was purchased also and rebuilt into a saponin plant with capacity of 100–200 t/a, which processes Dioscorea to be an intermediate midbody of drug–saponin. According to market survey, within 30–50 years, saponin is still in short supply as a raw material of drug, and the value will be higher if processed to be diene. Therefore, such forest-and-herb ecological economic program will possibly become the key industry in local area, and help farmers and Dioscorea produced by them to have stable income and sale channel respectively.

At the same time, together with relative sectors of local government, we set up environmental protection company, taking full responsibilitoes of operation and management on pollution treatment of Yilong lake and ecological economic construction. Together with local relative sectors, we also set up medicinal company, taking responsibilities of drug production and sale etc..

⑵In design and construction of lake, reseviror and river treatment engineering of Yiqiao in Tianjing, Zhouzhang in Jiangshu and Wenzhou in Zhejiang, the selection and design of ecological economic development project is decided upon adjustment and reformation of local industrial structure, such as: establishment of green food base, development of tourism etc.. Generally, the pattern of its management and operation mechanism is as follows:



A Think of Measurements to Control Eutrophication in China on the Basis of International Research Experience of Restoration of Eutrophic Lakes

Dai Shugui and Liu Guangliang
College of Environmental Science and Engineering, Nankai University, Tianjin, China

Abstract This paper gave a review of overseas studying trends in restoration and control of lake eutrophication at first. Management strategies for lake eutrophication in England and Wales and in Australia were overviewed. Combining International research experience with Chinese actual situation, preventing and curing measurements for lake eutrophication in China were suggested.
Key-words Lake eutrophication Restoration management strategy International research experience Suggestion

1 Overseas Studying Trends in Restoration and Control of Lake Eutrophication

The eutrophication of water body, especially lakes and reservoirs, is still one of important problems concerned with water resources and water environment obsessing many countries around the world. Extensive and in-depth research works have been done and lots of studying reports and papers have been published. The following text gave succinct presentations of typical cases.

1.1 The capabilities and needs of lake restoration [Carpenter SR. and Lathop RC. 1999]

Lake degradation results from excessive nutrient inputs, toxic substances, habitat loss, overfishing, species invasions and extirpations. The scientific basis of lake degradation is generally well understood, although each restoration project requires some level of new site-specific research. Remediation may require management actions which are difficult to implement for social or institutional reasons. Even where large-scale remediations are attempted, it is difficult to sustain scientific assessments for long enough to evaluate success. Collaborations of scientists and managers have sometimes succeeded in overcoming limitations to lake restoration, and produced important advances in our capability to restore lakes.

1.2 Multi-lake studies [Van der Molen DT. and Portielje R. 1999]

The relation between (inter)national programs aiming at nutrient load reduction and changes in eutrophication has been studied for 231 Dutch lakes over the period 1980–1996. Trends in total-phosphorus (P) and total-nitrogen (N) were negative corresponding with the significantly reduced P emission and the limited reduction of N emission in The Netherlands since the beginning of the 1980s. Negative trends in chlorophyll-a and positive trends in Secchi-disc transparency may be partly explained by reduced nutrient concentrations. The improvement of the water quality was found for all subsets of average depth, surface area, hydraulic retention time and soil type. Furthermore, the effect of restoration measures and meteorological conditions on the trends were studied. Biomanipulation resulted in an additional improvement of several water quality variables compared to lakes that were only subject to (inter)national programs on nutrient load reduction. The Netherlands succeeded in eutrophication control in the Naardermeer nature reserve by reduction of external nutrient load by the supply of phosphate-free water [Boostma, et al., 1999].

There was a report dealing with restoration of eutrophied shallow softwater lakes based upon carbon and phosphorus limitation [Roelofs, J.G.M 1996]. The plant production in very soft waters is often limited by low levels of inorganic carbon, nitrogen and/or phosphorus. A possible remedy is a combination of carbon-and phosphorus limitation. Many plants from eutrophic environments never occur in very soft waters, probably as a result of carbon limitation. In addition, mobilisation of phosphate is much lower in waters with very low bicarbonate levels. Restoration of a former oligotrophic softwater lake by reducing the inlet of calcareous surface water, in combination with removal of the organic sediment layer, appeared to be very successful.

1.3 Control of sediment phosphorus and internal phosphate flux

France scientists found that external phosphate load is large but internal flux also has to be taken into account during studies of the hydroelectric reservoir of Bort-les-Orgues. The potential of P release at the sediment-water interface was studied. The results of sequential extraction method showed that not all forms of phosphate are likely to be released. In Bort-les-Orgues about 80% of P, mostly iron-bound, was mobile. About 20% of P calcium-bound was immobile. The results of laboratory experiment showed that as long as oxygen concentration remained above 0.5 mg/L , no release was observed while phosphate and iron were released together when oxygen dropped to 0.5 mg/L and redox potential reached －350 mV at the sediment-water interface. This internal phosphate source should be taken into account in any project of lake restoration. Sequential extraction of phosphate and flux measurement are thus necessary tools for a better management of eutrophic water bodies [Ruban, V. and Demare, D 1996]. Dutch scientists found that sulphate and bicarbonate were key factors in sediment degradation and restoration of lake during studies on Lake Banen [Brouwer, E et al. 1999]. In many Dutch lakes, alkaline and sulphate-rich river water has been used to compensate for water losses. As a result, these waters have become eutrophied. In order to study the contribution of increased alkalinity to the eutrophication of softwater lakes a mesocosm experiment was designed. Two types of sediments were flooded with demineralized water containing 2 mmol/L bicarbonate ions. The upper centimetres changed from a brown soil with coarse organic particles to a fine black mud. The formation of degradation intermediates and some phosphate release were observed. This degradation was more evident in sediments flooded with demineralized water containing 4 mmol/L sulphate ions. In addition, sulphate consumption, sulphide production, bicarbonate production and enhanced phosphate release were observed in the sediment. And then the eutrophied, softwater Lake Banen has been isolated from river water inputs, and mud layers were removed to prevent sediment degradation and to lead to a return of the endangered macrophyte communities typical of softwater lakes.

1.4 Biological control of lake eutrophication

Scientists in Wisconsin University, U. S., have ever tested if biological method such as grazing could control eutrophication by fertilizing lakes that had contrasting food webs [Stephen R. Carpenter et al. 1995]. A lake with zooplanktivorous fishes and small grazers accumulated algal biomass as predicted by Vollenweider's model of eutrophication. A lake with piscivorous fishes and large grazers accumulated about half the algal biomass predicted by the model. However, blue-green algae bloomed in both lakes. It showed that grazing may control total algal biomass over a relatively wide range of P input rates, but may not suppress irruptions of nuisance algae.

Lake restoration in the Netherlands has been focused mainly on the control of external P loading from point sources. However, this approach did not result in the water quality desired. The algae-dominated turbid water state may be extremely stable, and then additional measures are necessary to remove certain 'blockages' such as: the persistent bloom of Oscillatoria algae, the P release from the lake sediments, and the abundance of fish, preventing zooplankton and submerged macrophytes from developing. An ecosystem approach to restore shallow lake was proposed [Hosper, S.H. 1998]. According to the concept of stable states, buffers and switches, priority should be given to fighting the Oscillatoria blooms. Winter flushing with water low in TP and algae proved to be an effective tool for reducing these blooms. Reduction of planktivorous fish, such as bream and roach, could enhance the top-down control of algae through the grazing by zooplankton, particularly by the large Daphnia species.

Reduction of Microcystis blooms was achieved by a combined ecotechnological strategy in Bautzen reservoir, a shallow, hypertrophic water in Eastern Saxony, Germany [Deppe T. et al. 1999]. This new type of water treatment technology was tested during two seasons (May–August 1996/1997). The technology is based on a combined lake-internal phosphorus precipitation and a transport of hypolimnetic water rich in free carbon dioxide into the upper layers. During the treatment periods, there were found both an increase of CO_2 concentrations in the mixed layer and an extension of the period in which free CO_2 was detected in the epilimnion. The concentrations of phosphorus could be lowered drastically in the whole water body. Microcystis was almost totally suppressed (1996) or appeared with a delay (1997) compared to the regular annual pattern observed before the treatment. In contrast to the preceding year (1995), diatoms played a major role in the summer phytoplankton during the treatment years (1996/1997).

1.5 Featured management

The Lake Balaton case study in Hungary provided an experience on modeling and management on eutrophication of shallow lakes [L. Somlyody et al. 1983]. The phenomenon of eutrophication is more irregular in character and less satisfactorily understood for shallow water bodies than for deep lakes. The structure of the research was based on a systems analytical approach which allowed the joint study of scientific and practical issues covering a wide range of different disciplines such as biology, chemistry, physics, hydrology, mathematics, economics, etc. The mathematical models developed in harmony and interaction with data collection and experimental work played a significant role in the project. Several existing methods were adopted for modeling the ecological and hydrophysical processes as well as water quality management in parallel with establishing new methodologies. At the end he research an expert committee was established in Hungary to elaborate recommendations for the government concerning the revision and modification of existing measures on water quality control and regional development. When these recommendations were authorized the relevant decisions were made.

In Denmark lake and catchment management was carried out [Jeppesen E. et al. 1999]. The majority of Danish lakes are highly eutrophic due to high nutrient input from domestic sources and agricultural activities. Reduced nutrient retention, and more rapid removal, in catchments as a result of agricultural drainage of wetlands and lakes and channelisation or culverting of streams also play a role. Attempts have recently been made to reduce nutrient loading on lakes by intervening at the source level and by improving the retention capacity of catchment areas. Meanwhile various physico-chemical restoration measures have been used, including dredging and oxidation of the hypolimnion with nitrate and oxygen. Biological restoration measures include reducing the abundance of cyprinids and promoting macrophyte recolonization by protecting germinal submerged macrophyte beds against grazing waterfowl and transplanting out macrophyte shoots. The findings to date indicate that macrophyte refuges and transplantation seem to be the most successful as restoration measures.

2 Management Strategy for Lake Eutrophication in Certain Countries

2.1 Management strategy on aquatic eutrophication in England and Wales [Paul L. 1998]

The Environment Agency of England and Wales (the Agency) has adopted an integrated approach to the management of the environment, as set out in its Environmental Strategy in 1997. With the awareness that eutrophication have an increasing political, scientific and public profile at national and international level the need to tackle nutrient enrichment was one of ten key issues highlighted in the Agency's recent report on the State of Fresh Waters in England and Wales. The aim was to mitigate adverse effects on both the ecology and legitimate uses of water and to reduce the threats to biodiversity and freshwater fisheries. The importance of eutrophication as a national water quality issue was highlighted in a report in 1998 in order to achieve a more sustainable balance between the needs of society and the health of freshwater ecosystems. Considering the nature and complexities of the problems and risks posed by eutrophication, the following key elements of management strategy were proposed:

⑴the promotion of a partnership approach to eutrophication management, at both local and national level;

⑵the adoption of a range of regulatory and other mechanisms (voluntary, collaborative, educational and economic), by the Agency and others, to reduce nutrient inputs to waters;

⑶a review of the arrangements for measuring the extent of eutrophication in different types of waters and the impacts of discharges and land use on water quality;

⑷the prioritisation of waters for management action on the basis of specified criteria. Initial proposed priorities are: waters where there are statutory requirements; or where water uses are adversely affected; or where special conservation interest is at risk; or where benefits can be delivered or deterioration prevented, with adequate confidence, at reasonable cost;

⑸the adoption of interim targets for eutrophication control in fresh waters, and the application of specific statutory;

⑹the management of eutrophication at site-specific level through the development of catchment-based action plans, with community involvement where appropriate, within the context of the national framework;

⑺the promotion of a wider understanding of the nature and significance of aquatic eutrophication; and

⑻a programme of research and development to improve scientific understanding of the eutrophication process.

Following sufficient consultation the Agency published and implemented a final version of the strategy in summer 1999.

2.2 National eutrophication management program in Australia [Ian Lawrence et al 2000]

In Austrlia the National Eutrophication Management Program was established in 1995, to provide the scientific underpinning necessary for the effective management of algal blooms. A large number of projects were funded by this organization. The primary focus of these projects has been analysis to better describe the factors driving algal growth and determining algal composition in reservoirs. For example, an important component of the Burrinjuck algal succession research project has been the development, in collaboration with managers, of guidelines that enable better management of reservoirs in limiting the incidence and severity of algal blooms. Reservoir managers' workshops with the theme of factors controlling algal growth and composition in reservoirs was held in January 2000. The content of this workshops dealt with factors determining algal growth and composition, reservoir management issues, management options, management information needs, management guidelines, monitoring implications, and further research needs.

Management options included: improved information related strategies–raising awareness of community and managers; catchment management strategies; and reservoir management strategies including inlet zone management strategies, control of draw-down rates and minimum reservoir levels, selection of off-take level, sediment redox management, mechanical aeration and oxygenation of bottom waters, bio-manipulation, sediment re-suspension management (turbidity), chemical coagulation of suspended soil particles or precipitation of nutrients, and use of algacides.

Management information needs included: better definition of management objectives, particularly in the case of multi-purpose reservoir operation; guidance on techniques for assessment of risk of algal bloom occurrence for local reservoirs and changing seasonal conditions; simple tools for determining the dominant pathway for local reservoirs; information on the range of possible options, including guidelines on the selection of options and decision support tools guiding reservoir operations; guidance on techniques for assessment of performance of options.

Management guidelines included an outline of reservoir and catchment management guidelines.

In order to respond to the information needs and reservoir operation decision guidelines, a range of monitoring programs are required. Monitoring covers operations related monitoring, performance assessment related monitoring, and system understanding related monitoring.

Research needs included: the form and pattern of delivery of nutrient and organic material to reservoirs; inlet and shallow depositional zone processes and impact of rapid drawdown; development of a reservoir classification system as the basis for translation of broadly based management option guidelines to local conditions; development of improved models for estimating mixing and light conditions.

3 Preventing and Curing Measurements for Lake Eutrophication in China

Large numbers of research and investigation works on eutrophication in lake and reservoir were done in China during past decade. Eutrophic state of major lakes and reservoirs in whole country has been investigated. Long-term research on eutrophication of key lakes including Dian Chi, Tai Hu, Chao Hu and other lakes such as Xi Hu in Hangzhou, Dong Hu in Wuhan, Yuqiao Reservoir in Tianjin, and Nan Hu in Changchun has gained some fruits and national prizes. At the same time a great amount of scientific papers, research reports even monographs were published. International scientific meeting on conservation and management of lake has ever presided by China. Significant curing measurements were performed in some lakes, but in point of whole country as a persistent ailment eutrophication of freshwater lake and reservoir was not mitigated remarkably. During project of ninth five years Dian Chi, Tai Hu and Chao Hu were placed on emphases of harnesing by National Environmental Protection Agency.

In fact comprehensive harnesing measurements such as sewage cutting, flushing, sediment dredging, biomanipulation, and removal of nitrogen and phosphorus have been applied in eutrophied lakes. Measurements focusing on prevention such as reduction of nitrogen and phosphorus inputs, establishment of benign ecologic balance in lake zone, and enhancement of management have been taken in most goodish lakes and reservoirs. However, these measurements took few effect, or temporarily became better then rebounded. Drawing experience from foreign countries and combining with practical situation in China, the following measurements that should be enhanced are to:

⑴popularize scientific knowledge about eutrophication by media and enhance public and decision-makers' awareness of crisis on surface freshwater;

⑵strengthen jural concept, in particular intensity of execution of law, and punish violation that emits water containing nutrients above stand level or other materials to make water deterioration arbitrarily into lakes and reservoirs;

⑶make efforts to prevent and alleviate natural disasters' adverse effect on lakes;

⑷organize collaborations of scientists whose studies dealt with eutrophication and managers and constitute measurements of prevention and restoration and feasible act and rules of management after consulting together;

⑸assort with the actions of related management branches and establish an incorporate system of management on eutrophication in lakes and reservoirs, at both local and national level;

⑹organize research and engineering practice of control and restoration of eutrophication in typically lakes, and set up an expert council for consultation;

⑺establish monitoring and information system of lake and reservoir eutrophication, and find out succession trends of lake ecosystem and water quality in time; and

⑻ promote international scientific exchange and cooperation, effectively use foreign experience for reference, and considering practical situation in China creatively stipulate for effective prevention and cure scheme on the basis of research.

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The Investigation on Water Pollution Prevention and Treatment Work of Dianchi Lake Catchment

Zhang Fengbao

The Office of Kunming Municipal Dianchi Lake Protection Commission, Yunnan, China

Abstract Based on the explanation of Dianchi Lake has great influence on the sustainable development of society and economy in Kunming area, and integrates with the present state of water environment and pollution prevention and treatment of Dianchi Lake, this article briefs and analyzes the measurements and progress has been adopted and made in water pollution prevention and treatment of Dianchi Lake by Yunnan provincial government. At same time, based on the practical experiences that had made in water pollution prevention and treatment work of Dianchi Lake in many years, this article also advances the countermeasure and measure for water pollution control, which is more scientific and more reasonable. These measures are strengthen the achievements of treatment, tighten the non-point sources pollution control.

Key-words Dianchi Lake Catchment Water Pollution Prevention and Treatment investigation

1 Background of Dianchi Lake

1.1 Natural conditions of Dianchi Lake

Dianchi Lake is a famous plateau freshwater lake of our country. It is located in the south end of Kunming Municipality and situated in the watershed of three water systems of Yangtse River, Red River and Pearl River. There are more than 20 rivers or canals flowing into the Lake. The lake water flows into Tanglang River and then into Pudu River and finally into Jinsha River through Haikou exit and Xiyuan Tunnel, which is controlled by the sluice gate. The rivers and canals mentioned above, the Lake water body and Tanglang River consist the water system of Lake Dianchi. This catchment, with an area of 2,920 square kilometers, is listed as the key water system protected by the State.

The Lake body is slightly in arc shape and arc back is eastward. North-to-south length of the lake is about 40km and the widest east-to-west is 12.5km. The lake shoreline is 163km. The average water depth is 4.4m, the maximum depth is 10.9m, water surface is 306km^2 and total storage capacity is 1.29 billion cubic meters when the water lever is 1,886.5m (above the Yellow Sea). In the north part of the lake, there is natural dam that divides the lake into southern and northern parts. There is only one shipping channel, which links the two parts of the lake. The southern lake, which is the main lake body, is called Waihai and the northern lake is called Caohai.

1.2 The position and function of Dianchi Lake

Dianchi Lake is the base for the production, development and existence of Kunming. It is not only the water resource for the industrial and agricultural production and potable water, but also it has multi-functions of water storage adjustment, flood control, tourism, navigation, aquatic product farming, climate regulation and hydraulic power and so on. It is a fundamental condition to maintain the ecological balance of Kunming areas. Kunming is the municipality that thrives and develops based on Dianchi Lake. The Lake basin has always been the biggest industrial base and economic mainstay of Yunnan Province. The total industrial output of this area accounts for 82.2% and 36.1% of that of Kunming Municipality and Yunnan province respectively while the total agricultural output accounts for 80% of Kunming's. In recent years, the synthetic economic strength of Kunming Municipality ranks 13th of the 50 powerful cities and the GDP of Kunming accounts for 1/3 of the Province, while the GDP of the Lake basin accounts for 80% of Kunming Municipality. It has become the common sense of all levels of government and the Kunming people, that is, no Kunming without Dianchi Lake. Therefore, it becomes a consistent decision and action of both provincial and municipal governments and the expectation of Kunming people to protect the Lake at any cost so as to provide necessary conditions for the sustainable development of Kunming.

1.3 The current situation of the Lake water environment of Dianchi Lake

Because of the natural evolvement and the activities of human being for many years, a series of problems occurred in the lake ecological environment, such as the lakebed rises, the lake surface shrinks, the water quantity decreases and the water pollution deteriorates.

Ⅰ. The current situation of the Lake water resource

Dianchi basin is an area short of water. The annual water resource per capita is only 300m^3, which is 1/9 of the national average. The annual average water resource of the catchment is only 550 million cubic meters. There is a water shortage of 100 million cubic meters in a normal year and of 20 million cubic meters for a dry year. The balance of the demand and supply of water resource can only rely on the municipal drainage and agricultural returning water. The reuse ratio achieves 36%.

With the development of the society and economy, the contradiction between water supply and demand will be intensified. It is forecasted that the water shortage for the normal year in 2010 will be 300 million cubic meters.

Water diversion from other catchment will be unavoidable.

Ⅱ. The current situation of Lake pollution

Dianchi Lake is located in the downstream of Kunming urban areas and it is the lowest zone of Dianchi catchment. Therefore, the lake becomes the final receiving water body for the industrial wastewater, domestic sewage and surface runoff from the city and the areas around the lake. The sewage inflow of the Lake (excluding runoff) achieves 175 million cubic meters, of this, domestic sewage accounts for 73% and industrial wastewater accounts for 27%.

The Lake water pollution is very severe. The water quality in Caohai is below Class Ⅴ. Water, the water body is extremely eutrophication and it loses its due functions. The water quality in Waihai is below Class Ⅳ and water is heavily eutrophicated. Blue green algae are extremely blooming from time to time.

2 The Implementation of the Comprehensive Management of the Lake Pollution

To some extent, the aggravation of Dianchi Lake water quality influence and restrict the sustainable social and economic development of Kunming Municipality and Yunnan Province. This severe issue of environmental pollution has aroused great concerns from the Central Party Committee, the State Council and Provincial and Municipal governments. The governments held meetings on the specific subject of the comprehensive management of Dianchi Lake pollution from central to local levels. Dianchi Lake Protection Regulation was stipulated and issued in 1988. A site-working meeting on Dianchi pollution abatement of the lake wills mainly base on engineering method, supplemented with biological measures. A series of comprehensive management approaches were adopted according to the ecological rules. These are: adopting separating system and interceptors, flood control and reduction and increase of use of good quality, dredging the lakebed, pollution load reduction and increase of storage, afforestation, the recovery of water resources, the water diversion to Kunming and the setup of new water resources. In 1996, Dianchi Lake was defined as one of ‘3 key lakes & 3 key rivers’ to abate pollution during the Ninth Five-year Plan period by the State Council. In the following year, a working conference on the water pollution prevention of Dianchi Lake basin was held in Kunming and the Ninth Five-year Plan and the year 2010 Plan on the Water Pollution Prevention of Dianchi Lake basin (Abbr. the PLAN hereinafter) was officially approved at conference. For years, under the pollution abatement guidance, which is mainly on engineering methods supplemented with biological approaches, the provincial and municipal governments input large investment on the pollution control projects and implemented a series of comprehensive management measures. This has effectively controlled the deteriorating tendency of the Lake pollution.

2.1 Aspects concerning engineering control

Ⅰ. The Point pollution control goes well

⑴Four sewage treatment plants (STP) were built with total daily capacity of 365 thousands tons. The treatment rate of the domestic sewage is more than 60%. Another four STPs are under construction (including 2 small STPs in the county towns) and No.1 STP is extended. It is predicated that the construction will be finished by next June. By then, an additional 220,000t sewage treatment capacity will be available and the total treatment capacity of the Municipality will achieve 585,000t/d and the sewage treatment rate will be more than 80%.

⑵The plan, which is called Zero O’clock Action, was implemented before ’99Horticultural Expo. This made the drainage from 249 of 253 key polluting enterprises to meet the standards while four enterprises whose drainage did not meet were demanded to shutdown for renovation.

Ⅱ. The abatement of internal polluting source achieves some preliminary effects

Under the solicitude and support of the Central Party Committee and the State Council, the first stage project of the lake sediment dredging was launched in Caohai during April 1998 to March 1999. The dredging area is 2.83 km^2 and the amount of 4.33 million tons of polluted sludge was dredged. A variety of pollutants, which include 20,588 t of TN, 1,715 t of TP and several thousand tons of heavy metals, were removed. The water body appearance of Caohai has been improved obviously.

At the moment, under the support from the State Planning & Development Commission, the preparations of the following dredging project for Caohai polluting sludge is ongoing. The project is expected to start from November 2000. The dredging area will be 1.93km^2 and the amount to be dredged is 1.91 million tons. Meanwhile, preparatory work for phase Ⅱ dredging project will be started.

Ⅲ. The pollution control on non-point source has been launched

⑴The pilot engineering of rural sanitation funded by the World Bank has been initiated at full-scale. Two key scientific research projects supported by the State Science Ministry, non-point source pollution control of Dianchi Lake and blue green algae and water hyacinth control of Dianchi Lake has started. The two research projects shall provide the non-point source pollution control of Dianchi Lake with mature and proper technique when the pollution control is implemented at full-scale in the next phase.

⑵The collection and disposal project of domestic solid waste funded by the World Bank is proceeding smoothly. To date, the two sanitary landfills with disposal capacity of 1,500 t/ d located at the eastern and western suburb respectively has been built up, and are expected to be put into operation in June next year.

⑶The ecological environmental improving project has been implemented (including 650 thousand mu of afforestation, 480 thousand mu of conservancy area, 40 thousand mu of returning farming land to forestry, and more 38 million trees planted. This project made the forest cover rate increase from 15.5% in 1987 to 32.9% nowadays. The forest cover rate in Songhuaba water source conservancy area achieves 50%.

⑷The implementation of the projects like sewage interceptor on the north bank of the lake, reconstruction of Panlongjiang and Daguan river courses, which link to the Lake, etc., reduces the pollution load upon the Lake.

Ⅳ. The water resource regulation and control

The project for reinforcing Songhuaba reservoir dam, updating the capacity of the reservoir, and untidily regulating the water use in Songhuaba reservoir and Dianchi Lake, project of Xiyuan tunnel and “2,258” water transportation project have been implemented. The construction of Zhangjiuhe water transportation project funded by introducing 3,800 million yuan of foreign funding has started and expected to be completed by year 2005.

2.2 Aspects concerning management pursuant to law

To establish and strengthen the legal system; and to establish institution to protect Lake

Dianchi in accordance with the law; to strengthen the basic scientific research work; to enforce the awareness raising work so as to enhance the awareness of the whole society to protect the lake; to strengthen the management of the Lake Dianchi, the boundary markers, which define the Lake area to be protected, are erected around the Lake water body. The objective responsibility system for the comprehensive management of the Lake pollution was established. More than 5,000 fish farming boxes and more than 1,170 powerboats were banned and over 50 quarries facing to and around the Lake were closed. To control the pollution source, phosphorous detergent is forbidden to sell and restricted to use within the Lake basin, so as to reduce the nitrogenous and phosphorous pollution upon the Lake. The economical means were adopted like increasing the water tariff, collecting drainage tariff, implementing water extraction license system and saving the water.

3 The investigation on the Water Pollution Prevention and Treatment in Dianchi Lake Basin in Future

3.1 Strengthen the management and consolidate the treatment achievements

Fully strengthen the due effects of urban sewage treatment works through the setting up of the supervision system for the operation. Strengthen the supervision for discharged industrial wastewater meet the standard, to prevent the old pollution sources are ‘ rebounded’. Control the development of urban and population scale according to the Kunming Urban Plan, and check the examination and approval of construction projects on strictly to stop the production of new pollution sources, and reduce the pollution of Dianchi Lake produced by nitrogen and phosphate. Meanwhile, perseveringly insist upon to ban the fish culture in net pen and motor fisherman in Dianchi Lake, the blasting mountain and quarrying on mountain faced to the Dianchi Lake, prohibit to sale and limit to use the phosphate-containing detergent within the Dianchi Lake basin, to further consolidate the achievements had been got in pollution prevention and treatment work of Dianchi Lake.

3.2 Take the non-point sources treatment as a point of important, speed the Dianchi Lake treatment pace

Implement completely *the Ninth Five-year Plan and the year 2010 Plan on the Water Pollution Prevention of Dianchi Lake basin*, promote continuously the implementation of the target-responsibility system of Dianchi Lake comprehensive treatment, and make great efforts to the key-points as following five aspects. The first is that completely implements the engineering of wastewater cleaning and diversion for drainage system, and Fully strengthen the effects of urban sewage treatment works. The second is that strengthen the research on the physical technology of non-point sources pollution control, and completely implements the every engineering measure of non-point sources pollution control so as to control and reduce the pollution of Dianchi Lake caused by non-point sources pollutants. The third is that implements the biological recovery system engineering within Dianchi Lake catchment. The fourth is that continuously implements the sludge dredging engineering in Dianchi Lake. The fifth is that looks for the new water resources and implement the new engineering for water diversion from other catchments.

For above-mentioned works, the key and difficult point is the control of non-point source pollution. The key point is: with the point pollution had been controlled basically, the internal sources control has been implemented progressively, now, the non-point sources pollution has become to be the biggest pollution source of Dianchi Lake. The difficult point is: there are various kinds of non-point source pollution with loose distribution and wide areas involved, which are produced and drained at random. Therefore, it is very difficult to look for a physical treatment technology that has a practicability and can be operated for the technology and economy.

Therefore, we should develop the research on the physical technology of non-point sources pollution control according to the general thinking of non-point sources pollution control drafted based on the *Plan, draw out the Construction Plan of Biological Agriculture and the Control of Rural Non-point Sources Pollution in Dianchi Lake catchment,* and implement the control measures of Dianchi Lake non-point sources pollution by stages and by zones.

Implement the measures of engineering afforestation (include the earthling and vegetation of quarry and field), close hillsides to facilitate afforestation, return the grain plots to forestry and soil and water conservation within the conservation areas of water resources.

In the Dianchi Lake basin that is a transition area, construct the ecological agriculture area pass through the measures of the adjustment of industrial structure, planting selection of crops with double high (high yield and high value) and double low (low fertilizer and low pollution), the construction of shelter forest belt and combined vegetation system and etc., Pass through the popularization of the utilization of high effective and low toxin pesticide and fertilizer, rational application of fertilizer, residual water recharge and land treatment to achieve the farmland with minority waste. Pass through the measures of training of channel, dike improvement, the construction of shelter forest belt and detritus pit to achieve the small catchment treatment. Pass through the disposal and utilization of solid waste (sanitation landfill, compost, methane and incineration) to improve the environmental sanitation in the towns and villages.

Within the lakeside area, implement the Caohai biological park and ecological recovery system engineering of lakeside area, which are composed of roads round the Lake, system of waste water interception and recharge, artificial wet land, foretank , shelter forest belt round the Lake and biological multi-recovery.

Although we have made the successive achievement in the working of Dianchi pollution control, but we still need to increase the investment to achieve the target of Dianchi Lake control defined in the Plan. In order to solve the problem of funds shortage, we should as the development of the west area to be a turning point, look for actively the multiple channels of funds, and change the present mode that all investments are relied on governments and the funds structure is single, to ensure the funds demand of Dianchi Lake treatment.

Protect Dianchi Lake Pursuant to Law & Strengthen the Lake Management

Zhang Fengbao

Kunming Municipal Dianchi Lake Protection Committee, Yunnan, China

Abstract Based on the analysis of present state and trend of Dianchi Lake pollution deteriorated day by day, this article points out that the problem of the treatment while polluting is the No. one factor, which causes finally the present state of Dianchi Lake deteriorated day by day. The writer points out the theory that the control and solve the environment pollution problem is as important as the management and treatment, both of them should be developed simultaneously according to his experiences accumulated in the process of working of Dianchi Lake protection and treatment done by himself for a long time, meanwhile, makes the investigation on the institution and improvement of regulations and laws concerned with the water pollution preventing and treatment, so as to the water pollution prevention and treatment of Dianchi Lake pursuant to law and strengthen the management, and pass through the management to promote the pollution treatment and control.

Key-words Pursuant to law Protect Dianchi Lake Strengthen Management

Dianchi Lake is the cradle of Kunming to thrive and develop. It is also an important condition to maintain the ecological balance of Kunming Municipality. There would be no Kunming without Dianchi Lake. Because of the long term intervene of human being and nature evolvement, the lake surface shrinks, the lakebed rises, the storage capacity decreases and the water quality degrades. This situation is threatening the existing conditions of Kunming people and also it is restricting the prosperity and development of Kunming Municipality and even Yunnan Province as well. The issues of Dianchi Lake pollution have aroused great concerns from various walks of people both at home and abroad and from the leaders of all levels.

To protect the Lake well, the governments have made a lot of efforts and also adopted a series of measures in legal, administrative, economic, technical and educational aspects, and increased the investment so as to speed up the steps of the Lake pollution control. Therefore, the pollution control has a good beginning and some effects have been achieved.

However, the pollution of Dianchi Lake is still very serious to date. Besides the natural reasons, the activities of human being are the main contributions to its deterioration. These harmful activities are as the uncontrolled invasion and occupation of water body, the unauthorized construction of various hotels and resorts on the lake beach, the setup of fish-farming weirs, the drainage of untreated sewage or waste water below the standards and the dumping solid waste into the rivers linking to the Lake, the illegal lumbering, the lack of inconsistent planning and the unlimited development and utilization of the Lake. There are more than 5,000 industries and a population over 2 million within Dianchi Lake catachment. If these harmful activities could not be prevented effectively, ultimately the pollution will be going on while pollution control is undertaken. And, the pollution control speed will never catch up with the pollution. If so, the trend of the Lake pollution can never be reversible. These dangerous acts of human beings upon the Lake are mainly resulted from the lack of legal management.

With the rapid social and economical development in recent years, the environmental problems are becoming intensified. Great attentions have been paid by the Party & Government. It has been clearly defined that environmental protection shall be a fundamental policy of the State. With various reforms going on, both guiding ideology and institutional construction for environmental management are becoming mature. In aspect of the guiding ideology, substantial change has been made and environmental protection approaches suitable for the current national practice have been found. It has been realized that the reliable solution to control and solve environmental pollution problem mainly shall base on the strengthening environmental management rather than the large investment and the using of sophisticated techniques. Environmental managements will advance the pollution control.

Therefore, the management is as important as control for the systematic project of the Lake protection. Both management and control shall be needed to speed up the Lake pollution reduction. Comparing to the pollution control, the management will spend less money within less time. This is an important ways to prevent the Lake environment from ongoing deterioration. Otherwise, control without management will not alleviate but aggravate the Lake pollution. It is becoming a common sense that we need 30% efforts in control and 70% in management to deal with the Lake pollution. Only a great deal of management will make the pollution control effective. Therefore, while controlling the Lake pollution, we must protect the Lake pursuant law, strengthen the Lake management and restrict the deeds harmful to the Lake so as to maintain sustainable development and provide better surviving conditions for the future generation.

How to protect the Lake pursuant to law and strengthen the Lake management? We should do as follows according to our own practice combining with the experiences from other regions:

1 Strengthen the Publicity and Education so as to Promote the Civil Awareness of the Lake Environment, of the Existence and of the Law

Every one and every enterprise or institution is the beneficiary of the Lake and it is also the polluter and the victim of the Lake. To protect the Lake, the first important thing is to strengthen the legal sense and environmental awareness for all people, especially for leaders. Those harmful tendencies that ignoring the long-term environment benefit while pursuing immediate interests and ignoring the overall benefits while chasing the local interests should be prevented. We must insist a guidance of harmonious developments both economy and environment from a macroscopic and strategic viewpoint. Therefore, we will persistently spend a great deal of efforts to publicize and implement *Dianchi Lake Protection Regulation* and the laws and regulations concerning environmental protection. Subsequently, this will establish a good social practice and custom of protecting Dianchi Lake by everyone. Protecting the Lake well shall be a social incumbent obligation for all Kunming people.

2 Complete the Legal System

The issuance and implementation of *Dianchi Lake Protection Regulation* brought the Lake protection into legal track. To manage the Lake on laws, good administrative regulations and counterpart policies should be prepared besides revising *Dianchi Lake Protection Regulation* so as to setup a complete legislation system. Thus, management can be carried out based on the laws and regulations. Illegal acts could be reclaimed and punished in time.

3 Strengthen Institutional Construction of Law Enforcement

Besides the laws and regulations, to protect the Lake we must set up authoritative institutions for Dianchi Lake management and powerful supervision team for the enforcement of Dianchi Lake Protection Regulation. Hence we must sort out and improve the Lake management system and strengthen unified management. This will form a comprehensive law enforcement system, where there are laws and regulations available for management, institutions for enforcement, supervisor for illegal acts, rules for punishment and investigation for breach.

4 Manage the Lake Strictly on Laws

Dianchi Lake Protection Regulation is a local regulation of our municipality. The issuance and implementation of this regulation is the first step to manage the Lake pursuant to law. Thereafter, it is more important to act legally and to enforce the law strictly. This is principal objective for this legislation. Hence, all enterprises, institutions and individuals must obey the rules in *Dianchi Lake Protection Regulation*. The governments and departments of all levels shall ensure that the laws are strictly observed and enforced and violations of the law are investigated and dealt with.

5 Establish Objective Responsibility System for the Comprehensive Management of the Lake

Protection and management of Dianchi Lake is a duty of the governments of all levels, as stipulated in *Dianchi Lake Protection Regulation*. Consequently, the detailed tasks for the comprehensive management of the Lake shall be assessed and examined within objective responsibility system for the governments and relevant departments of each level. The administrative leader responsibility system shall be implemented so as to ensure some achievements every year and to protect the Lake well.

6 Drive the Comprehensive Lake Management into the Market

The task of comprehensive Lake management is very hard. It will be very difficult to rely on the governments only. Gradually, we must drive the comprehensive Lake management into the market while setting up the socialist marketing economy. Some governmental acts will be turned into company performance. It shall be encouraged to save water and reduce drainage by means of policy regulation and economic lever. Production and use of environmental safe green products, such as non-phosphor detergent shall be popularized.

The task of protecting Dianchi Lake is a project for the existence of Kunming Municipality, even of Yunnan Province as well. It will benefit both the current and future generations. The Lake protection represents the fundamental interests of the most people of the Spring City and the Province. Therefore, we will definitely recover and improve the Lake ecological environment if we can enforce *Dianchi Lake Protection Regulation* seriously, make concerted efforts, protect the Lake pursuant to law and strengthen the Lake management while controlling its pollution. We are confident to make this high-plateau pearl brilliant again.

Sept. 15, 2000

Numerical Analysis on the Responses of Total Phosphorus to the Proposed Pollution Control Projects for Quilu Lake Using a Water-Sediment Coupled Total Phosphorus Model for Shallow and Eutrophic Lakes

Ma Shengwei Dai Zhengde

Mathematics Faculty of Yunnan University , Kunming, China

Abstract To compare the responses of total phosphorus concentrations in Qilu Lake to the proposed pollution control projects, a water-sediment coupled total phosphorus model for shallow and eutrophic lakes with limited data is developed, whose parameters are determined by combining core data analysis with mass balance method. Phosphorus exchanging in water-sediment interface, which includes settling, releasing and burial processes is emphasized. It is revealed that lowering the sediment release rate is very effective in short, middle and long terms, reducing the phosphorus loading is effective in middle and long terms, and dredging the active layer of lake sediment is only effective in short term.

Key-words Phosphorus Model Water-sediment interface Lake Pollution control

1 Introduction

For more than 30 years, the effect of sediment on lake water quality has been studied, but emphasis is often put on lab not numerical simulation, hence many interesting results cannot provide enough direct instruction for lake water pollution control and predication. Another problem in the studies is that standardized or widely accepted methods for the determination of some parameters such as release, settling and burial have not been developed; hence the data obtained by different methods are incomparable. (Dillon *et al.* 1993, Portielje *et al.* 1998)

To quantify the effect of sediment on total phosphorus(TP) concentrations in lake water, a coupled model, which includes at least two dependant variables :TP concentrations in the sediment and lake water, is essential. Several such models have been developed (Lorenzen *et al.* 1976, Rossi *et al.* 1991, Molen 1991, Chapra *et al.* 1991 and Molen *et al.* 1998).

Lorenzen *et al.* (1976) presented a very simple yet quite reasonable model to estimate the effect of the sediment on TP concentration in water by introducing mass transfer coefficient and exchangeable/non-exchangeable phosphorus in the sediment, which is very difficult to determine in field works. By introducing more reasonable conceptual assumptions, Chapra *et al.* (1991) revised Lorenzen model in several aspects such as settling area not the whole lake, burial process TP not exchangeable/non-exchangeable phosphorus and the effect of hypolimnetic dissolved oxygen on mass-transfer process.

Chapra model is not always reasonable. Firstly, some recent studies have shown that hypolimnetic dissolved oxygen doesn't affect lake's internal phosphorus cycling (Gachter *et al* 1998); secondly, settling/release area is very difficult to determine in practical field works, and in many small and eutrophic lakes in China, settling and release can almost be taken place in the whole lake (Shi 1989).

This paper use a simple method to solve the coupled equations analytically not numerically, and in parameter determination, a new method, which combines core data and mass balance method, is developed.

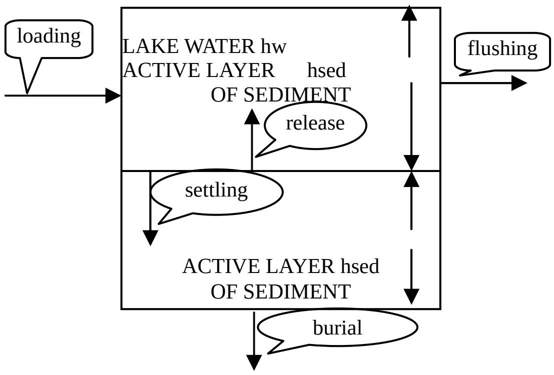

Fig. 1 Schematic diagram of the model system

2 Model Description

By simplifying TP cycling process (Fig.1) and neglect the flushing process, which is negligible in Qilu Lake, a lake to be studied in this paper (Ma *et al.* 1999), the governing equations of the coupled model can be written as:

$$\frac{dC_w}{dt} - \frac{V_r}{h_w}\cdot C_{sed} + \frac{V_s}{h_w}\cdot C_w = f \qquad (1)$$

$$\frac{dC_{sed}}{dt} - \frac{V_r}{h_{sed}}\cdot C_{sed} + \frac{V_s}{h_{sed}}\cdot C_w + \frac{V_b}{h_{sed}} = 0 \qquad (2)$$

Where, C_w, C_{sed}—TP concentrations in lake water and sediment respectively, g/m^3;

V_s—settling velocity of TP from lake water to the sediment, m/a;

V_r—TP release (mass transfer) rate from the sediment to the water, m/a;

V_b—burial/sedimentation rate of TP from the active layer to the permanent layer ,m/a;

h_w, h_{sed}—the mean depths of lake water and active sediment, m;

f—TP loading, g/m^3/a.

CASE 1: $\frac{dC_{sed}}{dt} = 0$ Then, $C_{sed}=C_{sed0}$, which is often assumed in the numerical study.

$$\text{Hence}\left(V_r + V_b\right)\cdot C_{sed} = V_s \cdot C_w$$

$$\frac{d\left(C_w \cdot e^{\frac{V_s}{hw}\cdot t}\right)}{dt} = f \cdot e^{\frac{V_s}{h_w}\cdot t} + \frac{V_r}{h_w}\cdot C_{sed0} \cdot e^{\frac{V_s}{h_w}\cdot t} \tag{3}$$

Then,equation (1)becomes:

CASE1 is IMPOSSIBLE if V_r, V_b and V_s all keep constant.

If only V_b varies with time, the solution for equation (3) is:

$$C_w(t) = C_{w0} \cdot e^{-\frac{V_s}{h_w}\cdot t} + C_{\mathrm{sed0}} \cdot \frac{V_r}{h_w}\left(1 - e^{-\frac{V_s}{h_w}\cdot t}\right) + f \cdot \frac{h_w}{V_s}\left(1 - e^{-\frac{V_s}{h_w}\cdot t}\right) \tag{4}$$

CASE2: Normal

Assuming that f, V_r, V_b and V_s all keep constant and, when $t = 0$, $C_{sed} = C_{sed0}$ from equation (2), csed can be written as

$$C_{sed}(t, C_w) = C_{sed0} \cdot e^{\frac{V_b+V_r}{h_{sed}}\cdot t} + \frac{V_s}{h_{sed}} \cdot \int_{\mathrm{t}}^{0} C_w \cdot e^{\frac{V_b+V_r}{h_{sed}}(\tau-1)} d\tau \tag{5}$$

Substituting (5) to (1), equation (1) becomes:

$$\frac{d\left(C_w \cdot e^{\frac{V_s}{h_w}\cdot t}\right)}{dt} = f \cdot e^{\frac{V_s}{h_w}\cdot t} + \frac{V_r}{h_w}\cdot C_{sed0} \cdot e^{\frac{V_s}{h_w} - \frac{V_b+V_r}{h_{\mathrm{sed}}}} + \frac{V_s \cdot V_r}{h_w \cdot h_{sed}} \cdot e^{\frac{V_s}{h_w}\cdot t} \int_{\mathrm{t}}^{0} C_w \cdot e^{\frac{V_b+V_r}{h_{sed}}(\tau-1)} d\tau \tag{6}$$

Hence,

$$\begin{aligned} C_w(t)\cdot e^{\frac{V_s}{h_w}\cdot t} &= C_{w0} + \int_{\mathrm{t}}^{0} f \cdot e^{\frac{V_s}{h_w}\cdot t} dt + \frac{V_r}{h_w}\cdot C_{sed0} \cdot \int_{\mathrm{t}}^{0} e^{\frac{V_s}{h_w} - \frac{V_b+V_r}{h_{sed}}} dt \\ &+ \frac{V_s \cdot V_r}{h_w \cdot h_{sed}} \int_{\mathrm{t}}^{0} e^{\frac{V_s}{h_w}\cdot t} \int_{\mathrm{t}}^{0} C_w(\sigma) \cdot e^{\frac{V_b+V_r}{h_{sed}}(\sigma-1)} d\sigma \cdot d\tau \end{aligned} \tag{7}$$

From equation (7), we can get:

$$\begin{aligned} C_w(t) &= C_{w0} \cdot e^{-\frac{V_s}{h_w}\cdot t} + \frac{h_w \cdot f}{V_s}\left(1 - e^{-\frac{V_s}{h_w}\cdot t}\right) + C_{sed0} \cdot \frac{V_r \cdot h_{sed}}{V_s \cdot h \cdot -(V_b + V_r)\cdot h_w} \cdot \left(e^{-\frac{V_b+V_r}{h_{sed}}\cdot t} - e^{-\frac{V_s}{h_w}\cdot t}\right) \\ &+ \frac{V_s \cdot V_r}{h_w \cdot h_{sed}} \int_{\mathrm{t}}^{0} e^{\frac{V_s}{h_w}\cdot t} \int_{\mathrm{t}}^{0} C_w(\sigma) \cdot e^{\frac{V_b+V_r}{h_{sed}}(\sigma-1)} d\sigma \cdot d\tau \end{aligned} \tag{8}$$

Assuming: $C_{w\max}(t) = \max(C_w(t))$

From (8), the solution for C_w , $C_{w\max}$, can be written as

$$\begin{aligned} C_{w\max}(t) &= C_{w0} \cdot e^{-\frac{V_s}{h_w}\cdot t} + \frac{h_w \cdot f}{V_s}\left(1 - e^{-\frac{V_s}{h_w}\cdot t}\right) + C_{sed0} \cdot \frac{V_r \cdot h_{sed}}{V_s \cdot h \cdot -(V_b + V_r)\cdot h_w} \cdot \left(e^{-\frac{V_b+V_r}{h_{sed}}\cdot t} - e^{-\frac{V_s}{h_w}\cdot t}\right) \\ C_{w\max} &\cdot \frac{V_r}{V_b \cdot V_r}\left(1 - e^{-\frac{V_s}{h_w}\cdot t}\right) - C_{w\max} \frac{V_s \cdot V_r \cdot h_{sed}}{h_{sed} \cdot V_s \cdot (V_b + V_r) - h_w \cdot (V_b + V_r)^2} \cdot \left(e^{-\frac{V_b+V_r}{h_{sed}}\cdot t} - e^{-\frac{V_s}{h_w}\cdot t}\right) \end{aligned} \tag{9}$$

Hence,

$$C_{w\max}(t)=\frac{C_{w0}\cdot e^{-\frac{V_s}{h_w}t}+\frac{h_w\cdot f}{V_s}\left(1-e^{-\frac{V_s}{h_w}t}\right)+C_{sed0}\cdot\frac{V_r\cdot h_{\mathrm{sed}}}{V_s\cdot h_w-(V_b+V_r)\cdot h_w}\left(e^{-\frac{V_b+V_r}{h_{sed}}t}-e^{-\frac{V_s}{h_w}t}\right)}{1-\frac{Vr}{V_b+V_r}\left(1-e^{-\frac{V_s}{hw}t}\right)+\frac{V_s\cdot V_r\cdot h_{\mathrm{sed}}}{h_{\mathrm{sed}}\cdot V_s\cdot(V_b+V_r)-h_w\cdot(V_b+V_r)^2}\cdot\left(e^{-\frac{V_s}{h_w}t}\right)} \quad (10)$$

From (4) and (10), it can be concluded that when $t\to+\infty$, the effects of the initial condition of sediment (C_{sed0}) are different in case 1 and case 2.

In case 1,

$$C_w(+\infty)=f\cdot\frac{h_w}{V_s}\cdot C_{sed0}\frac{V_r}{V_s}$$

While in case 2,

$$C_{w\max}(+\infty)=f\cdot\frac{h_w}{V_s}\cdot\frac{V_r+V_b}{V_s}$$

It should be noticed that $C_{w\max}(+\infty)$ is the stable solution of governing equations(1)–(2), hence the assumptions in case 2 is more reasonable.

Table 1 Morphometric characteristics of Qilu Lake

surface area (A)	35.9km^2
mean depth (h_w)	3.99m
maximum depth	6.8m
drainage area	354km^2

3 Model Application

3.1 Characteristics Qilu Lake

Qilu Lake is located in central Yunnan Province, southwest of P. R. China. Some morphometric characteristics of the lake is shown in Table 1. Water quality of the lake has been monitored 6 times every year(usually in March, August and November, and twice in the months) since 1985, and before that the frequency is lower and the time is not fixed. From 1991 to 1996 the load of TP has been calculated based on land use, water consumption, industry and precipitation (Yunnan Province Environmental Protection Bureau,1998). Concentrations of TP in the lake water and TP mass balance are shown in Table 2. The sediment is sampled and tested in 1999, some characteristics of the active layer is shown in Table 3 (Yunnan Provincial Department of Geology and Minerals, 1999)

Table 2 Characteristics of active sediment in Qilu Lake

density	$2.3 g/cm^3$
thickness(h_{sed})	0.19m
phosphorus content	0.08%
burial/sedimentation rate (V_b) (Cs-137)	0.47cm/a
averaged grain size (D)	1.15μm
porosity	0.9

3.2 Parameters determination

(1) $S-R$

In the system (Fig.1), phosphorus mass balance can be written as:

$$S - R = L - F - \Delta w$$

Where, L—phosphorus loading (kg/a);

F—TP flushed (kg/a);

Δw —the increment of TP storage in the water;

S—the mass of TP settled from the water to the sediment;

R—S—the mass of TP released from the sediment to the water.

From Table 2, $S-R=34.39\times10^3$ kg/a (averaged from 1991 to 1996)

(2) V_s

Settling velocity of particles in lake water can be calculated by Stokes function when Reynolds number (Re)<<1, which can be easily met as the averaged diameter is only 1.15μm, and density is 2.3×10^3 kg/m^3 in Qilu Lake.

$$V_s = 9.81\times\frac{1}{18\cdot\mu}\left(\rho_{sed} - \rho_w\right)\cdot D^2$$

Where, $\mu = V\cdot\rho_w = 0.001$ kg/m/s (when water temperature is 15℃);

ρ_{sed} , ρ_w —the density of the sediment and water respectively;

D—the averaged diameter of the particles.

From Table 3, v_s=6.94m/a

Table 3 Phosphorus loading, flushing, storage variation for Qilu Lake

	Loading(t/a)	Flushing(t/a)	storage ariation(t/a)	TP concentrationin the lake(mg/L)
1991	35.78	2.81		
1992	29.49	2.49	–0.12	0.061
1993	38.43	4.01	2.77	0.064
1994	44.24	1.98	0.29	0.092
1995	37.80	3.30	1.07	0.069
1996	39.51	3.07	–2.95	0.077
mean	37.54	2.94	0.212	0.058

(3) V_r

$$S - R = V_s\cdot A\cdot C_w - V_r\cdot A\cdot C_{sed}$$

hence, V_r=0.0062m/a

(4) V_b

V_b can be directly calculated by Cs-137.

4 Results and Discussions

Assuming that the phosphorus load keeps the averaged level from 1991 to 1996, initial condition of C_w=0.058mg/L (1996) and C_{sed}=184mg/L (1999), and the morphometric characteristics will keep constant in 100 years, some results are illustrated in Fig.2–6.

4.1 Comparison of (4) and (10)

Fig.2 and fig.3 show that case 1 (C_{sed} = C_{sed0}, the solution is (4)) underestimates TP concentrations in lake water and TP approach stable state in a shorter time. The reason is that the feedback of the sediment is underestimate in case 1, as a fact, S−R is bigger than $V_b \cdot A \cdot C_{sed}$, hence C_{sed} > C_{sed0}.

In fig.3, TP concentrations in lake water decrease in the first short time both in case1 and case2, the reason is that fast component of the solution ($e^{-\frac{V_s}{h_w}t}$)dominates at first, then slow component ($1-e^{-\frac{V_s}{h_w}t}, e^{-\frac{V_b+V_r}{h_{sed}}t} - e^{-\frac{V_s}{h_w}t}$)dominates (Chapra *et. al.* 1983).

Comparison of Different Pollution Control Methods

For Qilu Lake, several pollution control methods are recommended, but the effect of which on TP concentrations in the waterbody have not been calculated. Three major methods are shown in Table 4.

Table 4 Different pollution control methods for Qilu Lake

symbol	description
Normal	no methods is adopted
50%-input	phosphorus loading reduced by 50%
25%C_{sed0}	sediment dredging, initial TP concentration decrease by 75%
25% V_r	sediment release control, V_r decrease by 75%

(1) Long Term

In long term (fig.4), suppressing the release from water to sediment is very effective that means the feedback of the sediment has considerable effect on TP concentration in the water, from fig. 4, release rate decrease by 75%, TP concentration in the water can decline about 45%. While dredging the sediment has no effect on TP concentration in the water, that means, inn long term, sediment feedback will be affected by phosphorus loading, which determines the stable TP concentrations in the lake.

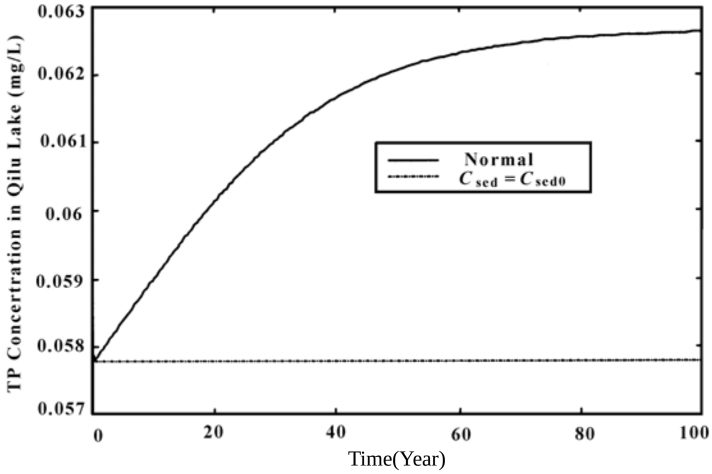

Fig.2 Comparision of model results:long trem

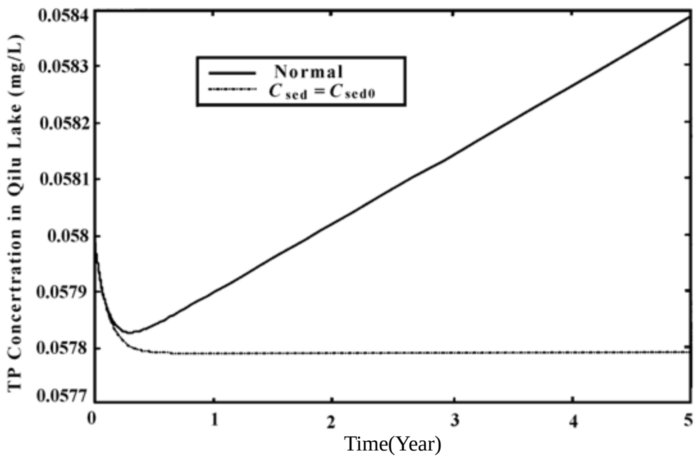

Fig.3 Comparision of model results:short trem

Hence, in long term, it can be concluded that i) lowering phosphorus load and suppressing the release are the two most effective methods; ii) in natural systems, sediment feedback itself cannot affect TP concentration in the water.

(2) Middle Term

In middle term (fig.5), suppressing the release is the most effective method, sediment dredging and load lowering is also effective, that means in middle term, sediment feedback is mainly controlled by release rate V_r, the initial condition C_{sed0} also has certain effect, but its effect decreases as time goes.

(3) Short Term

In short term (fig.6), sediment dredging and release suppressing have no distinct differences, and release suppressing can achieve stable state in very short time, hence, in short term, sediment feedback is controlled by both release rate and the initial condition of the sediment, C_{sed0}.

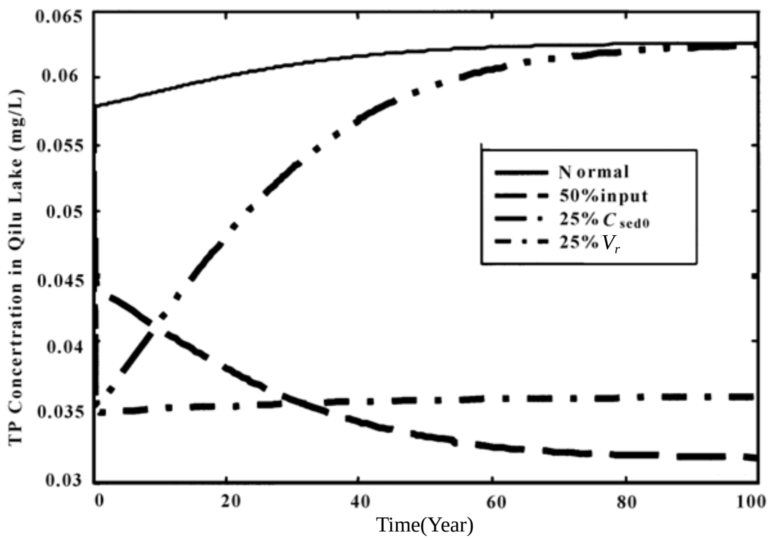

Fig. 4 Comparision of treating methods:long trem

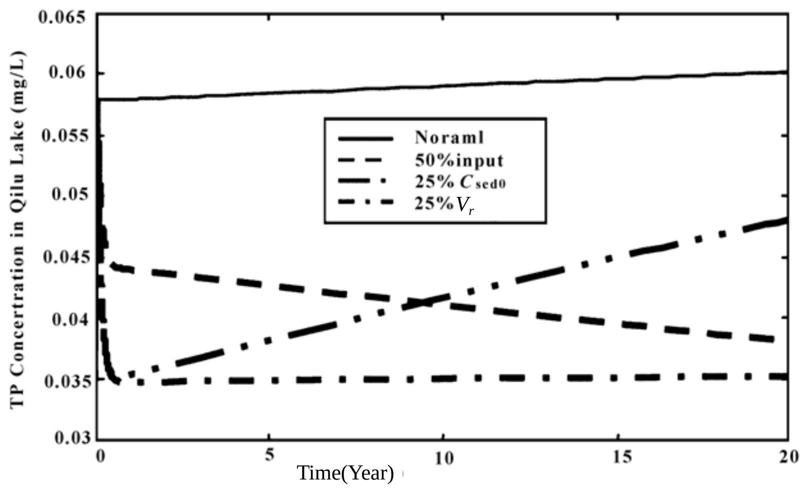

Fig.5 Comparision of treating methods:middle trem

5 Conclusions

⑴Sediment feedback in Qilu Lake can affect TP concentration in the water in short and middle terms; while in long term, the feedback is affected by phosphorus loading.

⑵The parameters in the model can be determined by combining mass balance method and core data.

⑶The coupled model presented in the paper can be applied in the study of comparing different pollution control methods for a lake, where the data is very limited.

⑷For Qilu Lake, lowering the sediment release rate is very effective in short, middle and long terms, reducing the phosphorus loading is effective in middle and long terms, and dredging the active layer of lake sediment is only effective in short term.

⑸Some calibration work should be done and the model will include phytoplankton in the future.

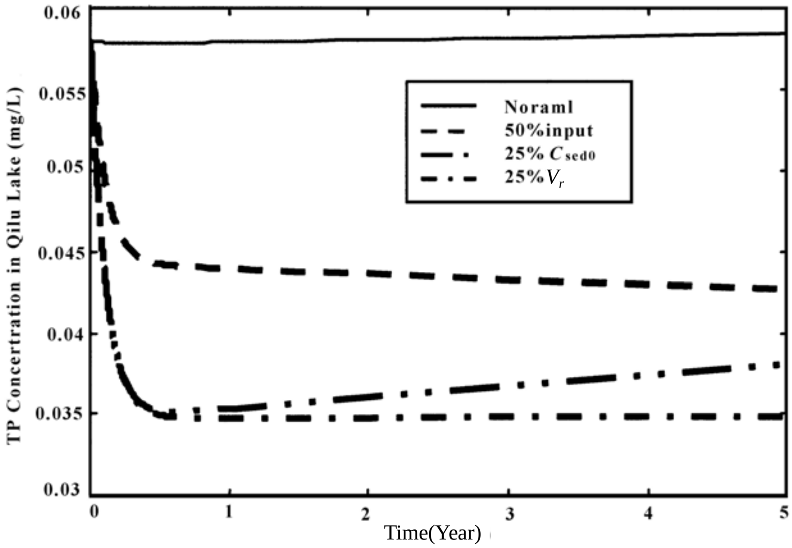

Fig. 6 Comparision of treating methods:short trem

6 Acknowledgements

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Studies on Productivity Control-an ecological and Biological Way for the Algal Bloom Control in a Hyper-eutrophic Lake Dianchi

Liu Yongding

Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan 430072, P.R. China

Tel: (86-27) 87884371, or (86-871) 7323852,

Fax: (86-27) 87875132, e-mail: liuyd@ihb.ac.cn

Running title: *Productivity Control of Bloom-forming Cyanobacteria in Eutrophic Lake Dianchi*

Abstract Based on investigations of toxic cyanobacterial bloom in China and intensively in the hyper-eutrophic Lake Dianchi, Kunming, Yunnan, it was reported hereon the principles of technological route conducting currently by the author's team for bloom control. The experimental area in Dianchi Lake is of 6 km^2. The main measures are to establish appropriate populations of phytoplanktonic consumers like fishes, zooplankton, zoobenthos and the aquatic higher plants so as to control the productivity of bloom-forming cyanobacteria as well as to recover the healthy lake ecosystem. In combination, research results and technological development also were reported in regarding the bloom-forming cyanobacteria as cleaning organisms and make use of the big biomass harvested from the lake into fertilizers, fine chemicals like phycocyanin, polysaccharides.

Key-words Ecotechnology Eutrophic lake Water bloom *Microcystis* Cyanotoxin Microalgal biomass Algal biotechnology Phycocyanin Polysaccharides Detoxification

1 Introduction

There are growing ecological, environmental and health (especially human health) concerns over the expansion of toxic and other harmful algal blooms (HAB) in a variety of aquatic ecosystems. HAB appeared frequently in lakes, man-made impoundments (e.g., reservoirs, agriculture and aquaculture ponds), rivers, estuaries and coastal waters worldwide. HAB caused unpleasant taste and odor, generated anoxia and hypoxia, altered or disrupted food web. Heavy water blooms always brought aquatic animal died, drinking water quality decreased (even not useable), vegetation in lakes damaged, fishery and tourism discontinued. The controls of HAB, especially of cyanobacterial blooms in freshwater bodies become a hard task in front of scientists and administrators on regional and global scales. Scientists have made many efforts in the researches on harmful algal bloom (HAB) in the past years. Many scientific results have been published on the ecology, ecophysiology, ecotoxinology and ecotoxicology of toxic cyanobacteria. The topics in the hot concern were:

* Supported by the CAS and Yunnan cooperative project, and the state key project on *Cyanobacterial bloom control in Lake Dianchi*

- Detection and characterization of toxic cyanobacteria;
- Novel toxins, mechanisms, organisms, and toxic episodes;
- Toxins and other harmful substances;
- Biosynthesis and regulation of cyanotoxins;
- The functional roles of toxins from the perspective of cyanobacteria;
- From cultures to blooms: Clarifying harmful bloom dynamics in the laboratory and field;
- Ecology and biotic interactions of harmful bloom-forming cyanobacteria;
- Environmental monitoring and risk assessments of cyanotoxins, taste and odor causing compounds;
- Human alteration and manipulation of toxic cyanobacteria, including watershed management for bloom control and removal methods for toxins in water supplies;
- Manifestations and consequences of toxic cyanobacteria on environmental quality and human health: WHO guidelines for cyanotoxins (e.g. microcystins) in drinking and bathing waters.
- Improved analytical, immunological and molecular detection and characterization techniques that have helped identify noxious strains, their geographic distributions and habitats.

However, there is not much on the control especially biological and ecological control of the bloom-forming algae.

On the other hand, cyanobacterial bloom, cyanotoxins are invariably linked with water supply, which is and will be a serious problem in the new century of the world. In China, this problem displayed as water resources short, water distribution unbalanced and water quality decreased. According to the environment bulletin of the country, water quality in China is getting worse, being aggravated by the contradiction between water supply and demand. Severe water pollution and water shortage have become the two main obstacles in China's lasting utilization of water resources. Undoubtedly, the increasing eutrophication in fresh water bodies was caused by the increase of human activities. It is more obvious in the Yangtze River basin, since that area is one of the most active economic area in China and mostly plentiful of lakes. Three seriously polluted lakes, Dianchi Lake, Caohu Lake and Taihu Lake all located in the Changjiang (Yangtze) River basin. Chinese government has announced to treat pollution in these lakes with a priority.

Both scientific and social requirements called people to understand the causes of blooms, to determine the sources, fates and consequences of HAB in food webs and fisheries. For the management of aquatic ecosystem and water supply, it is necessary to develop the enhanced predictive and early warning capability to forecast the occurrence and impact of heavy cyanobacterial bloom. In addition, it is necessary to explore means for the mitigation, control of the toxic blooms so that to protect the freshwater bodies more comprehensively and effectively.

By chance of supports from the Ministry of Science and Technology, the Yunnan Provincial Government and the Chinese Academy of Sciences, The author’s team investigated:

- A countrywide investigation on toxic cyanobacterial blooms, the occurrence, species composition, distribution of bloom-forming blue-greens, especially of the toxin-producing ones, since the middle of 1980';

- Investigation on: the routine items in limnology also on biomass estimation, seasonal & diurnal rhythm, causes of formation;
- To develop a effective way to control the serious bloom and to help establishing a well running lake ecosystem.

Now the author's team is still conducting research projects in Lake Dianchi, a typical hyper-eutrophic shallow but big lake in the Yangtze River Basin. Hereon part of the results is reported on ecotechnology in combination with the application of microalgal biotechnology to control the bloom-forming cyanobacteria. The contexts in this report are partly from the previous results, partly from the current conducting work with discussions.

2 Materials and Methods

2.1 Location of the intensive investigation

Except investigation on water bloom and toxic cyanobacteria in various areas of China, intensive work was conducted in a big suburb lake, Lake Dianchi of the capital city Kunming of Yunnan Province in the southwestern China. The lake located within 102° 30′–102° 47′E，24° 40′–25° 02′N. The lake surface area is 306 km^2 at altitude 1886 meters above the Yellow Sea level with mean depth around 4.7 m and the annual average water temperature around 17℃–18℃. For the experiments of bloom control, the authors' team established an experimental enclosure of 6.1km^2 within 102° 41.8′–102° 44.6′E, 24° 55.0′–24° 56.1′N in the lake.

2.2 Field investigation of cyanobacterial bloom in Lake Dianchi

Samplings of 11 sites were taken for 10 times in Dianchi Lake during April 1997 to May 1998. Each sample was treated to count the cell number and the related biological, physical and chemical variable factors. Those included Chl.a, dry weight of algae, total nitrogen (TN), total phosphorus (TP), total dissolved phosphorus (TDP), dissolved phosphorus (DP, also known as DRP, dissolved reactive phosphorus), Chlorophyll a and Secchi Disk. All the variable parameters were analysed according to Jin and Tu (1990) and referred to *Criteria of Investigation on Eutrophication* issued by the Chinese EPA.

2.3 Algal biomass harvesting

Facilities for harvesting blooming algae were established by shore of the lake with self-designed and self-made machines, which were composed of pumps, gravity sieves, dryers and disintegrators. New technology for efficiency enhancement is under conduct.

2.4 Extraction of phycocyanin

With harvested bloom-forming cyanobacterial materials, phycocyanin was extracted after cell breaking by freezing and thawing. Refer to Jin Chuanying et al. (1999).

2.5 Extraction of algal polysaccharides

Hot water-soluble polysaccharides were extracted from harvested materials of bloom-forming cyanobacteria. Refer to Huang Zebo et al. (1999).

2.6 Feed and fertilizer production with algal powder

The harvested biomass of bloom-forming cyanobacteria was firstly treated for detoxicification, then it was used as a part of components to turn out fertilizer and feed additives. See SHEN Yinwu et al (1999, final report of the cooperative project No. 96S005 of the Chinese Academy of Sciences and the Provincial Government of Yunnan, on *Turning algal bloom into utilizable resources*).

2.7 Ecotechnology or eco-environmental engineering for the control of cyanobacterial bloom

The current project conducting is aimed at aiding the establishment of a healthy and well running ecosystem. It is similar but not really the same of ecological restoration and remediation at this stage. The main technological route is, through controlling the productivity of the dominant bloom-forming cyanobacteria by phytoplanktonic consumers and water cleaning organisms to maintain an ecological restriction on the population growth of blooming species. Three principles are set up for the technique selection: effective, environment safe, economically feasible. The work is composed of five principal parts. They are（1）Biological control with fishes, zooplankton and zoobenthos;（2）Recovering aquatic higher plants;（3）Mechanical removing off and make use of the cyanobacterial biomass;（4）Monitoring and management of the influences of toxic cyanobacterial bloom on the lake ecosystem;（5）Feasible technological scheme for scaling up.

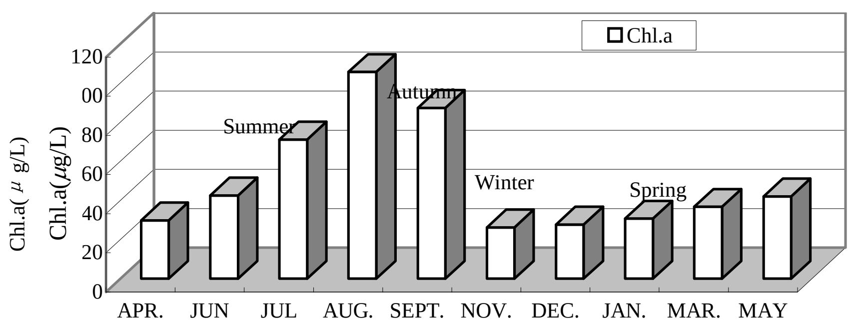

Fig. 1 Seasonal variation of chlorophyll contents in the main part of Dianchi Lake

3 Results and Discussion

3.1 Toxic water bloom in China and in the Lake Dianchi

Cyanobacterial blooms were the most prominent in eutrophic freshwater bodies of China. Among those, *Microcystis* spp. and strains were found in all water bodies investigated countrywide by the team of the authors. The investigated locations are:

The lakes Chenghai, Dianchi, Xinyun, Erhai in the West;

The lakes in Inner Mongolia and in Beijing of the North;

Taihu Lake, Dianshan Lake of Shanghai in the East;

Donghu Lake of Wuhan, Caohu Lake in the Central; and

The lakes in Guangdong and Hainan of the South.

Table 1 Toxins from bloom-forming cyanobacteria (blue-green algae)

Main types of toxins	Chemical structures	Molecularweight	Type organism	LD_{50} μg/kg mouse bioassay
Microcystin	peptide	909–1063	M.aeruginosa	50–100
Nodularin	peptide	824	N.spumigena	50–100
Aphantoxin	alkaloid	300–400	A.flos-aquae	10
Anatoxin-a	alkaloid	65	A.flos-aquae	200
Anatoxin-a(s)	alkaloid	252	A.flos-aquae	20
Cylindrosper-mopsin	alkaloid	415	C.raciborskii	

Toxins from blooms of *Microcystis*, *Anabaena*, *Nodularia*, *Oscillatoria and Aphanizomenon* were determined from lakes, ponds.

Table 2 Variances in microcystin content and composition in cells of M. viridis grown in different pH in MA medium

pH	Content	Composition (%)		
	(μg mg^{-1} dry cells)	RR	YR	LR
7.0	6.330	84.0	0.6	15.4
7.8	3.491	78.8	1.2	20.0
8.6	2.670	82.0	1.0	17.0
9.2	4.750	82.1	0.9	17.0

Table 3 Effect of light intensity on the toxin production of Microcystis viridis grown under 15℃ and 25℃

PFR (μEinstein m^{-2} s^{-1})	Content of toxins (μg mg^{-1} dry cells) 15℃	25℃
15	2.757	3.127
30	2.962	2.716
60	2.249	2.317
100	2.585	1.971

In Lake Dianchi, the bloom occurred seriously in the whole year since the climate is quite promotive and stable there. The highest concentration of Chlorophyll a always appeared in the late summer and autumn as shown in Figure 1.

Annually, 60 species of planktonic algae were found in Dianchi Lake. Among those, 19 species were of Cyanophyta, 34 of Chlorophyta, 4 of Bacillaoriophyta, 1 of Pyrrophyta and 1 of Xanthophyta. Comparing to the historic data, the species diversity of algae decreased dramatically in the past ten years. Blue-green algae become dominant from spring through late autumn. The most dominant species in Lake Dianchi is Microcystis aeruginosa, M. viridis and M. weissenbergii. Due to the frequent wind from southwest pushing the floated bloom to the northern part of the lake, the cyanobacterial cell concentration along the northern shore reached up to 3×10^9 cell·L^{-1} currently in Dianchi.

3.2 Biological bases for the control of the bloom

In order to search an efficient, environment safe and economic way to control the bloom, technology with biological, ecological and physical methods would be the best choice. Thus, the causes of bloom formation, seasonal and diurnal rhythm, morphological characters and the growth physiology were carried into studies(Fig.2, other data shown in previous publications of the team).

Table 4 Variances in microcystin content and composition in cells of *M. viridis* grown in different temperature

Temperature (℃)	Content (μg mg^{-1} dry cells)	Composition (%)		
		RR	YR	LR
15	3.705	71.3	3.9	24.8
20	3.563	71.3	3.8	24.9
25	3.580	69.3	5.6	25.1
30	3.490	65.9	6.9	27.2

The toxin profiles of the dominant species like *Microcystis viridis* was also worked out. Table 2, 3 and 4 showed that, the content and compositions of toxin microcystin in cells of *M. viridis* were related to pH, temperature and light intensity.

Results also showed that, the contents and compositions of toxins changed with the morphological transformation of colony shape to single cell of *M. viridis* under certain conditions, as indicated in Figures 2 and 3. It is interesting to have found out the difference of toxin compositions in two types of cell. The total microcystin content of the single celled culture was below 1.2 mg/g, less than half of the colony shaped culture by detecting Dha^7 microcystin-RR, Dha^7 microcystin-YR and Dha^7 microcystin-LR of both single-celled and colony shaped *M. viridis*.

3.3 Eco-engineering of removing and utilizing algae for cyanobacterial bloom control

To develop effective and environment safe ways to control the serious bloom in addition to those of controlling the point, non-point, inner source pollution, two questions are reasonably to be answered. ①Is it possible to inhibit the productivity of planktonic algae to control the bloom? ② Is it possible to regard the bloom-forming algae as cleaning organisms in eutrophic lakes?

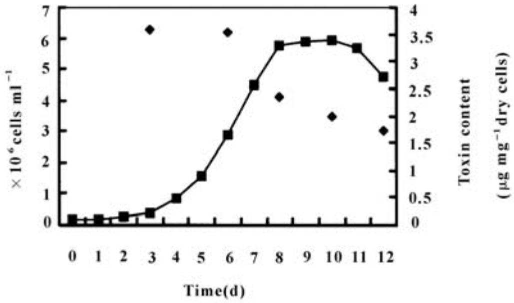

Fig. 2 Toxin production and growth rate of *Microcystis viridis* grown in batch culture.
Toxins represent the sum of [Dha^7] microcystin-RR, YR and LR.
■ growth curve , ◆toxin contents.

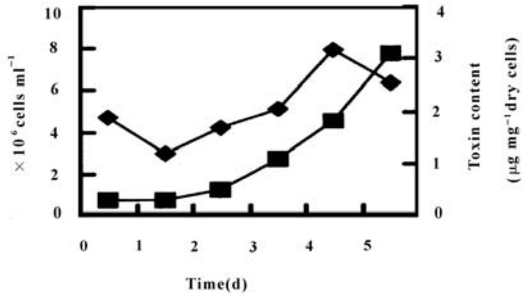

Figure 3. Time course of toxin production and growth rate of M. viridis after transferring from nitrogen-deficient MA medium to complete MA medium.
Toxins represent the sum of [Dha7] microcystin-RR, YR and LR.

For answering the first question, a state key project is conducting in Lake Dianchi to enhance the populations of algae-consuming organisms (fishes, zooplankton, bacteria and phycophage, as biological manipulation), and to help establishing a well running lake ecosystems. For the second question, a positive answer could to be sketched up by the authors' work in the past years. The main idea is to harvest the biomass of bloom-forming algae so that the nutrient load in water bodies could be decreased by remove off the organic substance. Then the algal biomass could be utilized further with microalgal biotechnology.

(1)Taking the algal biomass of the water bodies could remove out a big amount of nitrogen and phosphorus from the eutrophic lake. The ability of nutrient removing could be comparable with a sewage plant capable of treating thousand tons of wastewater per day since the standing crop of bloomed blue-green algae in Lake Dianchi is about 10,000 tons with a continuous increase.

(2)Harvesting algae by means of gravity sieves was feasible. An amount of 21.86×10^3 kg algal biomass was achieved in an experiment for 100 d in 1998. After removing the bloom with filtration and dehydration, thewater quality was enhanced.

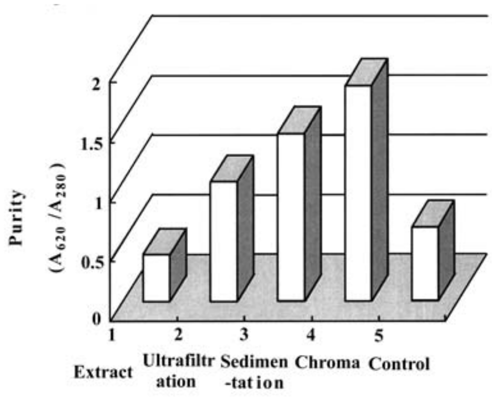

Fig. 4 Purity of cyanophycin products with different processing

⑶Harvested biomass was dried with solar radiation plus hot

wind by a blast furnace in a closed plastic green house of $110m^2$, drying 30–60 kg algal powder every two days (210 kg • d^{-1} f.wt.) in average. Algal powder contained 8 to 10 % of moisture, 43%–49 % of protein in content, the cost of manufacture is 3.0–4.0 yuan RMB (CNY)/kg. It could be used as raw materials in processing.

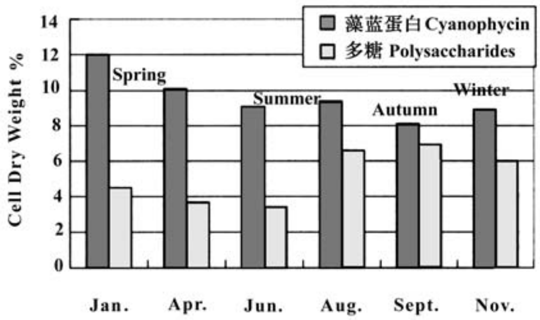

Fig. 5 Seasonal variance of cellular cyanophycin and polysaccharides in cells from the main part of Lake Dianchi in 1997

⑷Fresh harvested or dried algal biomass was processed into fertilizer and extracted for phycocyanin production. The purity of phycocyanin out of the bloom biomass from Lake Dianchi reached to 1.2—–2.0 as expressed in A_{620}/A_{280} with proper method as shown in figure 4.

Since the material is naturally harvested, the content of cellular constituent like phycocyanin and polysaccharides varied with seasons as showed in figure 5. This result indicated a technique base for the processing of bloomed algal biomass.

Table 5 Efficiency of repeated freezing and thawing for phycocyanin extraction

Freezing and thawing the first time	Freezing and thawing the second time	Freezing and thawing the third time
～67％	～19％	～14％

The processing started from breaking the cells with freezing and thawing. Table 5 and 6 showed that, both the efficiency and the purity of phycocyanin are higher after the first time freezing and thawing. About 70% of phycocyanin could be extracted, the post processing is easier with higher purity.

⑸Feed or fertilizer manufacture were made in water bloom control combining with the control of water hyacinth to remove N and P from the Lake, if heavy metals under control. Problem existed in the production of animal feed with *Microcystis* biomass. Such feeds caused liver sickness, eat-refuse and disorder in growth.

⑹Experiments for detoxification with alkali, chloride of lime，and ozone were carried out. Using ozone was much better than others were.

Table 6 Purity of phycocyanin (A_{620}/A_{280}) affected with the frequency of freezing and thawing

Extracts from Freezing and thawing, the first time	Extracts from Freezing and thawing, the second time	Extracts from Freezing and thawing, the third time
~ 0.65	~ 0.53	0.53

3.4 Currently experiments of productivity control on cyanobacterial bloom control in Lake Dianchi as a discussion

As mentioned in the above, the author's team is going to find a positive answer of the question "*Is it possible to inhibit the productivity of planktonic algae to control the bloom?* "in Lake Dianchi.

Why does *Microcystis* form bloom seriously in eutrophic lakes? Experimental results and putative biological mechanisms could give the conceptual answer. This kind of cyanobacteria flourish because of their high abilities in competition, a variety of factors affected the bloom formation such as,

Physical factors

- Exchange rate of water, or retention time of water
- Vertical disturbance of water in large scale
- Admixing of water in small scale
- Solar radiation variances and shielding effects
- Temperature

Chemical factors

- pH variances
- Input of nutrients (Nitrogenous and phosphorous substances)
- Salinity variances
- Trace element variance

Biological competitive ability

- High efficiency in concentrating and utilizing inorganic carbon dioxide, the carbon dioxide concentrating mechanism (CCM)
- Ability in atmospheric nitrogen fixation by some species of cyanobacteria
- Cellular mechanism of gas vasicular to regulate the cell floating
- Effective competition for trace elements and growth substances
- Growth tolerance under low light intensity
- Extremely strong vitality, and
- Probably some of the self-producing cyanotoxins like microcystins functioning as growth promoting substance in the population expansion (private communication)
- Normally there will be a succession of dominant phytoplankton in shallow freshwater lakes, Cyanobacterial bloom always appeared in later summer and autumn following diatoms (Bacillaoriophytes), Pyrrophytes and Chlorophytes. However, in the hyper-eutrophic water bodies, the diversity of phytoplankton decreased dramatically. Populations of cyanobacteria become dominant from the early spring through autumn.

Since the complexity in the occurrence of cyanobacterial bloom, the prediction and the management of which are much difficult. For the control or prevention of the cyanobacterial bloom, many different measures had been developed. The current scheme for productivity control are roughly shown in Figure 6.

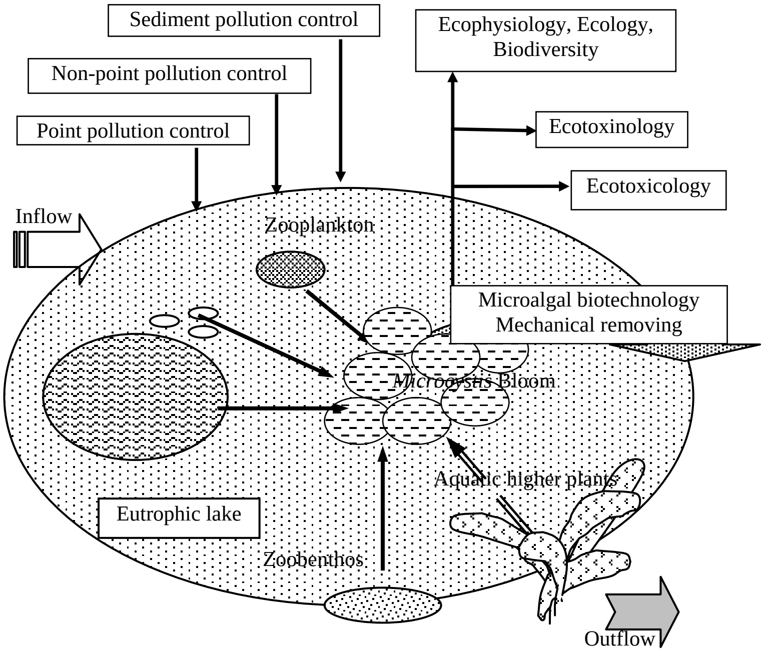

Fig. 6 Schematic illustration of the productivity control of bloom-forming cyanobacteria

4 Conclusion

Geographic expansion of toxic blooms is a serious problem in almost all over the world with human activities, though some people thought it may be a product of increasing scientific and public awareness of the environmental and health problems. It is well known that the bloom-forming cyanobacterial are a prime indictor of nutrient –enrichment in aquatic ecosystems. With the increasing knowledge of cyanobacterial ecophysiology, and the additional ecological evidence novel techniques and strategies for monitoring and controlling of blooms have been developed. Since physical/chemical perturbations of watersheds and their receiving waters is implicated in the global spread of toxic strains, it is possible to design targeted ecosystem management plans in order to mitigate the harmful effects of noxious cyanobacteria. Therefore, the most feasible way of controlling cyanobacterial bloom is at the restoration or re-establishment of healthy ecosystem. This is a long-term, systematic and comprehensive task in front of the human society.

For selecting useful technology for the control of cyanobacterial bloom, effective, environmentally safe and economically feasible would be the basic criteria. The possibility to regard the bloom-forming algae as cleaning organisms in eutrophic lakes and to make use of such kind of huge biomass is practicable from the results of the author’s team. An experiment in 6.1km^2 enclosure is ongoing now. To decrease the productivity of bloom-forming cyanobacteria in eutrophic lakes associated with restoring a healthy ecosystem would be possible to be realized, but it is time consumed.

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国际特邀专家

姓 名	简　　介
松井三郎(Saburo Matsui)	教授国际湖泊环境委员会(ILEC)　常务理事　秘书长 Director,　Research Center for Environmental Quality Control, Kyoto University, Japan　日本
Dr. Murray Charlton	Lake Research Branch Research and Applications Branch, National Water Research Institute, Canada Centre for Inland Waters, Canada　加拿大
Dr. Takehiro Nakamura (中村武洋)	联合国环境署水部　中国项目主管 Junior Programme Officer Freshwater Unit UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP)
小岛贞男	教授，日本高级技术顾问　日本　　　Nihon Suido Consultants Co., LTD
Prof. 稻森悠平(Yuhei Inamori)	研究员，日本国立环境研究所 The National Institute for Environmental Studies, Japan　日本
Prof. Kachur Anatoly. N.	俄罗斯科学院太平洋地质研究所　副所长　教授 Deputy Diretor of　Pacific Institute of Geography, FEB RAS，, Russian　俄罗斯
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Prof. Ing.Alberto T.J.Calcagno	研究员，Member of ILEC, Argentina　阿根廷
Dr. 岛谷幸宏 (YukihiroShimatani)	研究员，日本建设省土木研究所 教授　日本
Prof. Friedrich Recknagel	澳大利亚 教授，University of Adelaide, Department Soil & Water，　Australia　澳大利亚
Dr. Semykina Galina	研究员，Head of Center for Environmental Monitoring of Primorrsk for Hydrometeoroligy and Environmental Monitoring, Russia　俄罗斯
Prof. Gaunghao Chen	香港科技大学教授，Department of Civil Engineering Hong Kong University of Science &Technology, Hong Kong　中国香港
Prof. Ju-Chang Huang	香港科技大学教授，Department of Civil Engineering Hong Kong Uniiversity of Science &Technology, Hong Kong　中国香港
Prof. Vera Istvanovics	Water Resources Research Group of the Hungarian Academy of Sciences, Department of Sanitary Engineering, Budapest University of Technology and Economics, Hungary　匈牙利
Dr. Deok-Gil Rhee	研究员，Director　Water Quality Research Department National Institute of Environmental Research Environmental Research Complex, Korea　韩国
Dr. Hae-Kyung Park	研究员，Researcher　Water Microbiology Division Water Quality Research Department National Institute of Environmental Research Environmental Research Complex, Korea 韩国
Dr. Jonas Fejes	研究员，Aquatic Environmental Specialist Swedish Environmental Research Institute(IVL), Sweden　瑞典
Dr. Bjoern Faafeng	研究员，Limnologist Norewegian Institute for Water Research(NIVA), Norway　挪威
Prof. 须藤隆一	教授，Department of Civil Engineering Tohoku University, Japan　日本

刘鸿亮	中国工程院　院士，中国环境科学研究院　教授
汤鸿霄	中国工程院　院士，中国科学院生态环境中心　教授
钱　易	中国工程院　院士，清华大学环工系　教授
金相灿	教授，中国环境科学研究院　水环境研究所 所长　国际湖泊环境委员会(ILEC) 理事
屠清瑛	教授，中国科学院南京湖泊与地理研究所
戴树桂	教授，南开大学研究生院第一副院长　南开大学环境科学系主任
卞有生	研究员，北京环境科学研究院 副总工程师　国家城市污染控制工程中心生态工程部主任
薛纪瑜	教授，北京师范大学 环境科学研究所
刘永定	副所长　教授，中科院武汉水生生物研究所　副所长
刘树坤	教授，中国水利水电科学研究院　中国灾害与环境研究中心　水力学研究所
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程文明	高工，安徽省巢湖水资源办　主任
王　云	教授，上海华东师范大学　环境科学系
孔海南	教授，上海交通大学 环境学院
汪小泉	高工，浙江省环境监测中心站 站长
王开明	高工，巢湖污染综合治理工程指挥部 主任　巢湖市环保分局巢湖分局局长
张天华	高工，西藏自治区环保局 副局长　区环境科学研究所　所长
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李亚威	高工，内蒙古自治区环境科学研究所 副所长