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Assessment of water pollution control strategies: a case study for the Dianchi Lake

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Abstract: Lake eutrophication has increasingly become a major environmental issue in China. Although significant efforts have been made towards its resolution in the last decade, most of the implemented control strategies are fragmented, and the formation of policy lacks of sound scientific basis and long-term objectives. Taking the well-known Dianchi Lake as a case study, this paper presented a comprehensive assessment for the effectiveness of various eutrophication control strategies. It is expected that the concluding lessons would have a major implication to future eutrophication control.

Keywords: pollution control; eutrophication; Dianchi Lake; assessment

Introduction

Dianchi catchment is located in the middle of Yun-Cui Plateau in the southwest of China. The catchment area is 2920 km^2, with the south-to-north distance spanning over 114 km and the east-to-west only 25.6 km. Of the catchment, 69.5% are hilly and mountainous lands, 20.2% are plain and basin, and the other 10.3% is the Dianchi Lake. The annual rainfall rate is 874 mm, but it shows a significant uneven distribution. 80% of rains happens in the rainfall season. On the contrast, the annual temperature changes far less dynamic and the averaged temperature is 14.7℃, with an annual sunlight as high as 2200 h.

Adjacent to Kunming City, the capital of Yunnan Province, Dianchi Lake itself is also in a narrow shape, with the south-to-north distance spanning over 40 km and the east-to-west only 7.5 km. Its total volume is approximately 1.29×10^{10} km^3, at an average water depth only 4m, and a 2—3 years' hydrological retention time. The lake is physically divided into two parts, i.e., Chao-Hai and Wai-Hai, at the proportions of 2.7% and 97.3% respectively.

The dominant environmental problem in Dianchi catchment is eutrophication. The reason for that is in two aspects. First, as a large shallow plateau lake, the local climatic conditions of high irradiation and temperature, the clear rainfall seasonal pattern, as well as the slow hydrological exchange rate, lead to Dianchi liable to eutrophication. Second, the catchment runoff drains a significant amount of N and P nutrients into the Dianchi Lake via over twenty rivers, which pass through towns and villages, farmlands and phosphate mines. The amount of nutrients drained is particularly significant when the rainfall flows over those intensive agricultural lands which is close to the lake and the runoff is discharged directly into the lake via intensively distributed ditches. Over the last two decades, the rapid social and economic development of the Dianchi catchment considerably increases the N and P loads to the lake. The enhanced accumulation of nutrients in the lake provides thus the last major condition for the formation of eutrophication, i.e., the essential amounts of nutrients (IKES, 1992).

1 The control strategies

Control of water pollution in the Dianchi Lake began in the 1980s. But early work was dominantly characterized by scientific research and fragmented trial engineering practices. An integrated control strategy and engineering practices are only available since 1990s, as summarized below.

1.1 Enforcement of legislation and regulations

In addition to the amended national water environmental laws and regulations, the "Dianchi Protection Regulations" and "Integrated Control Outline of Dianchi Catchment" are specifically drawn up for the alleviation of eutrophication in the Dianchi Lake. Together with other regulations regarding the management of environmental funds and collection of pollution fees, these regulations provide a legal basis for various

campaigns targeting towards some specific activities with clear consequences of water eutrophication. The important ones include the elimination of cage-fish farming and automatic fishing boats in the Dianchi Lake; regulating the operation of mining practices; tightening the approval of new projects. In addition, land reclamation from, and dumping of rubbish to, the lake was banned. Thirty-two small yet seriously polluted enterprises were closed down, and sales and use of P-detergents were prohibited in the Dianchi catchment.

1.2 Increasing the treatment capacity of urban and industrial wastewater

Four centralized wastewater treatment plants were built from 1991, the current total treatment capacity is 360000 t/d, and 60% of urban domestic wastewater was treated. In 1998, the reduced COD loads to the lake by those plants were approximately 13002 ton. Likewise, significant progress was achieved for the treatment of industrial wastewater in the last a few years. Of the 257 major enterprises in the catchment, 253 of them have satisfied wastewater discharge standards, and the remaining four were either closed down or moving out of the catchment due to the difficulty for treating their wastewater. Thereafter, the COD, total N and P loads from industries have been reduced 79%, 79% and 90% respectively as compared with the loads of 1995,

1.3 Selective removal of nutrient-rich waters

Since eutrophication in Chao-Hai was much severer than in Wai-Hai, a channel was built in 1992 to withdraw nutrient-rich waters from Chao-Hai during the rainfall season. The objective for doing so was in two aspects. On the one hand, it could prevent the dispersion of seriously polluted waters from dispersing into Wai-Hai. On the other hand, it could reduce the overall nutrient contents of the waterbody. Over the four months from June to October in 1999, 30 million m^3 of water was replaced per month, which noticeably improved the water quality in Chao-Hai.

1.4 Sediment dredging in Chao-Hai

The sediment dredging in Chao-Hai began in April 1998. Up to now, 4240000m^3 of nutrient-rich slurry was removed. This is equivalent to the removal of 14929t TN and 2978t TP from the sediments. The water quality in the dredging area was significantly improved, as TN, TP and COD was decreased 36.4%, 64.7% and 37.8% respectively.

1.5 Mechanical harvesting and chemical control

Mechanical harvesting of algae from the lake began from April 1999 as an urgent strategy to provide immediate relief from unacceptable scenes. In half year's time, 1542m^3 of algae-rich water was treated, which contains 71000t of fresh algae and 60000t of macrophytes. Application of specific chemicals to kill algae was also under trials in four sensitive areas around the same time. The total tested areas are 3.35 km^2 and the period lasted about two months. After chemical application, the Secchi depth was increased from 0.25—0.3m to 0.5—0.7m, and chlorophyll-α was decreased from 250—377 mg/m^3 to 164—176 mg/m^3.

In addition to the above actions, the scales of which are still mostly under expending, other control strategies are also under investigation, including the establishment of macrophyte clean zones at the out of rivers to the lake, and the treatment of urban and agricultural wastes. But most important is that recent attention is dominantly directed towards non-point sources control, a consequence that source-pollution has been, or will be, largely under control.

2 The changes of water quality

In spite of the large investment on eutrophication control in Dianchi catchment over the last decade (approximately 4 billion RMB Yuan), the improvement of water quality in Dianchi Lake is only noticeable in Chao-Hai, while the water quality of Wai-Hai is actually deteriorating. Although the scenic appearance, in particular the Secchi depth, in Chao-Hai has been significantly improved and the phosphate content is greatly reduced, up to 41%, its NH_4-N and total N is increased, and Chao-Hai is still in the state of eutrophication. In Wai-Hai, however, BOD_5, NH_4-N, total N and total P are steadily increasing, of

which total N was increased 20%, NH_4-N between 47.7 and 102.5%, and total P around 80% from year 1993 to 1998. Considering other water quality parameters, in fact, Wai-Hai can only be classified as between category IV and V, the overall state of Wai-Hai is in or close to hypertrophic condition (Yunnan EPA, 1997).

3 Comments and conclusions

Given the scales and determination of eutrophication control in the Dianchi catchment over the last decade, the control objective can only now be said partially achieved. The reason for that could be summarized as follows:

Dianchi catchment is one of the most intensively exploited and developed areas in the southwest of China. Due to the rapid economic development over the last two decades, pollutant loads discharged to the Dianchi Lake have experienced a significant increase, which has surpassed the loads reduced by eutrophication control strategies. In other words, the major control strategies, though mostly directed towards the correct direction in terms of international experiences, are not implemented in full and thus less effective (Ryding, 1989). For instance, the treatment rate of urban wastewater is only 13% over the entire catchment in year 1998. Even in Kunming City, if considering urban runoff, the treatment rate is only 11.5%.

The control strategies have only been effectively implemented in the late 1990s, though evidence of eutrophication is widely detected in the 1980s. Earlier efforts were mainly diverted towards various, often inconclusive, research activities. Although studies and investigation about Dianchi's eutrophication can be traced back to early 1980s, the first integrated control plan was only drawn up recently, and the plan itself is still far from satisfactory. The initial delay for the implementation of effective control strategies is in no doubt responsible for the difficulty of remedying the eutrophication facing today.

As illustrated early, eutrophication control in Dianchi catchment has always been struggling for seeking the balances between short-term symptom relief and long-term cure of eutrophication. Often the weighing is unfortunately inclined to the short-term actions, a result possibly from institutional drawbacks. One of such examples is the operation of large scale sediment dredging when nutrients drainage sources are far from effective control.

There has long been a lack of integrated cost-effective analysis of applied control strategies in the Dianchi catchment, so it is the lack of the identification of key control processes and the priority of control actions. It leads thus to a situation that the tested or applied control actions are in a large number, yet it is unclear the effectiveness of each action. This makes it very difficult for decision-maker to determine where, when and on what scale each action should be applied. Thereafter, that it is far from clear whether the applied control strategies are economically sound and feasible.

It has been postulated that with current eutrophication control intensity, the COD_{Mn}, TP and TN discharged to the lake in 2000 will still be 19%, 9% and 16% respectively higher than the loads of 1995. Deterioration of the lake water quality seems inevitable. Such a formidable task could only be tackled via a cost-effective, well-coordinated and integrated control strategy, which is not available in the past of Dianchi eutrophication plan.

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