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Water Quality Analysis and Recommendations through Comprehensive Pollution Index Method

--Take Qilu Lake as Example

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Abstract: Recently, the quality of surface water has become one of significant environmental planning and management issues in China. To investigate the quality of surface water, three monitoring sites, such as Majiawan Site, Huxin Site and Huguan Site, have been established by Qilu Lake, located in the north of Tonghai County, Yuxi Region, Yunnan Province, by Chinese government. In this paper, we applied comprehensive pollution index method to analyze and monitor water quality, obtained a series of determination factors which could be used to differentiate V class and Interior V class of the water quality of Qilu Lake. Accordingly, we suggest relevant recommendations from the aspects of engineering measures, chemical and biological methods.
Key words: Qilu Lake; Water Quality Comprehensive Pollution Index; Water Quality Analysis

INTRODUCTION TO QILU LAKE

Qilu Lake is located in the north of Tonghai County, Yuxi Region, Yunnan Province. It is also called as Tonghai Lake, belonging to Pan River System. It has an area of over 40 km^2, a depth of 4 m with a maximum depth of 15 m, and a volume of 1.5 km^3. Its lake altitude is 1796 m. Qilu Lake is a north-east-south-west-rectangular shape, with about 10.4 km from east to west and about 3.5 km from north to south. The lake shoreline is about 32 km. The water gradually increases from west to east. Qilu Lake, a eutrophic lake, was formed because of the fall of terrain. The major pollution largely comes from organic pollution, nitrogen and phosphorus pollution. The annual average temperature is about 15.6 ℃. As important water resource of Tonghai County, Qilu Lake serves as industrial and agricultural water usage, water storage, flood control, shipping, tourism, aquaculture, and so forth. Therefore, Qilu Lake is called as "Mother Lake" by Tonghai County, and regarded as the elementary foundation of existent and economic development of Tonghai County.

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1. MATERIAL AND METHODOLOGY

1.1 Comprehensive Pollution Index Method

Water quality comprehensive pollution index was calculated upon unit pollution index evaluation. In terms of the characteristics of Qilu Lake pollution, we selected representative pollutants to calculate water quality comprehensive pollution index, including permanganate index, BOD_5, COD, ammonia nitrogen, total phosphorus, etc. (Although the content of dissolved oxygen exceeded, we didn't regard it as one of major pollutants. Indeed, the high content of dissolved oxygen was due to other pollutants, and it was difficult to calculate relevant index.)

Calculation of Unit Pollution Index:

$Pi=Ci/Si$ (2-1)

Ci – Measured concentration of pollutant;

Si – Standard value of relevant category.

Calculation of Comprehensive Pollution Index:

$P\ i=1=1/n\ \sum Pi$ (2-2)

n：8, it refers to the 8 projects for evaluation;

According to the value of water quality comprehensive pollution index, it can be categorized as qualified, basic qualified, polluted, and severe polluted, as follows:

Qualified: $P \leqslant 0.8$

Basic qualified: $0.8<P\leqslant 1.0$

Polluted: $1.0<P\leqslant 2.0$

Severe polluted: $P>2.0$

1.2 Nemerow Index Method

American scholar N.L. Nemerow pointed out Nemerow Index in his book, *Scientific Stream Pollution Analysis*. Nemerow selected several indicators as water quality index, such as temperature, color, transparency, pH, E. coli, total dissolved solids, suspended solids, total nitrogen, alkalinity, chlorine, iron and manganese, sulfate, and dissolved oxygen.

PI=｛〖(Ci/Sij)^2 Average＋(Ci/Sij)^2 Maximum〗^2/2｝^(1/2) (2-3)

PIj – j category water usage index

Ci – i category pollutant measured concentration, mg/L

Sij – j category water usage index according to i pollutant, mg/L.

When $Ci/Lij \leqslant 1.0$, Ci/Lij is Measured Value;

When $Ci/Lij>1.0$, $Ci/Lij=1.0+5lg(Ci/Lij)$;

Table 1
Nemerow Index Pollution Category

Category	I	II	III	IV	V
	Clean	Light Polluted	Polluted	Heavy Polluted	Severe Polluted
P	<1	[1，2)	[2，3)	[3，5)	≥5

Nemerow method is adopted to analyze the eutrophication of lakes from the perspective nitrogen source: large quantity of ammonia and nitrate nitrogen is transmitted into water system by agricultural runoff. The balance of nitrogen is hence changed. It leads to rapid proliferation of some kinds of algae species which can occupy a large amount of water surface. After these kinds of algae species die, they will be dissolved because of bacteria. Accordingly, it results in the increase of organics in water system; therefore, a great deal of fishes will die owing to the shortage of oxygen.

2. ANALYSIS AND RESULTS

2.1 Calculation of Annual Water Quality Comprehensive Index

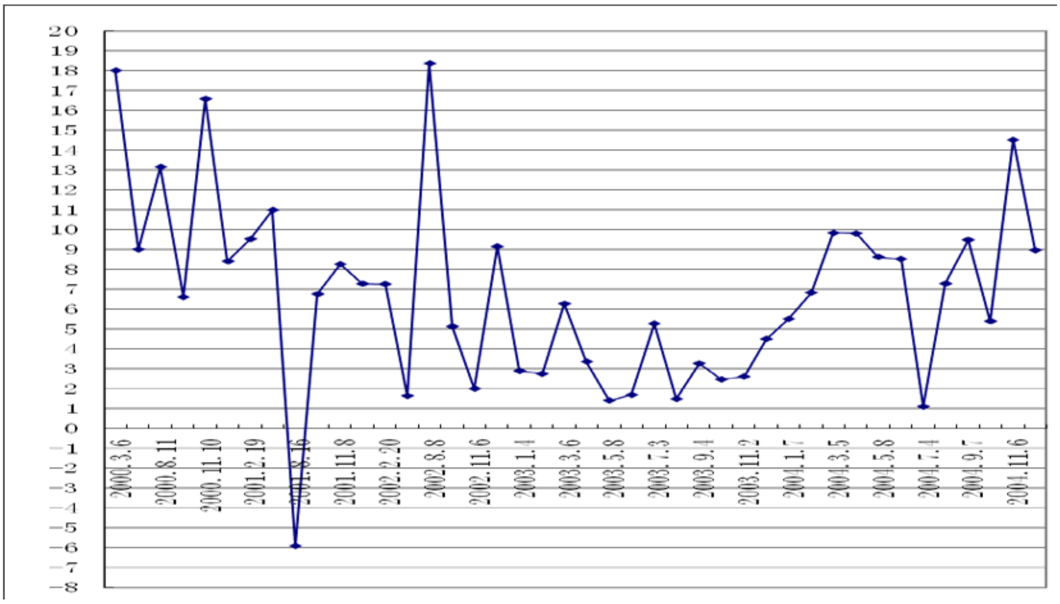


Figure 1. Majiawan Monitoring Site Water Quality Index with the Change of Time

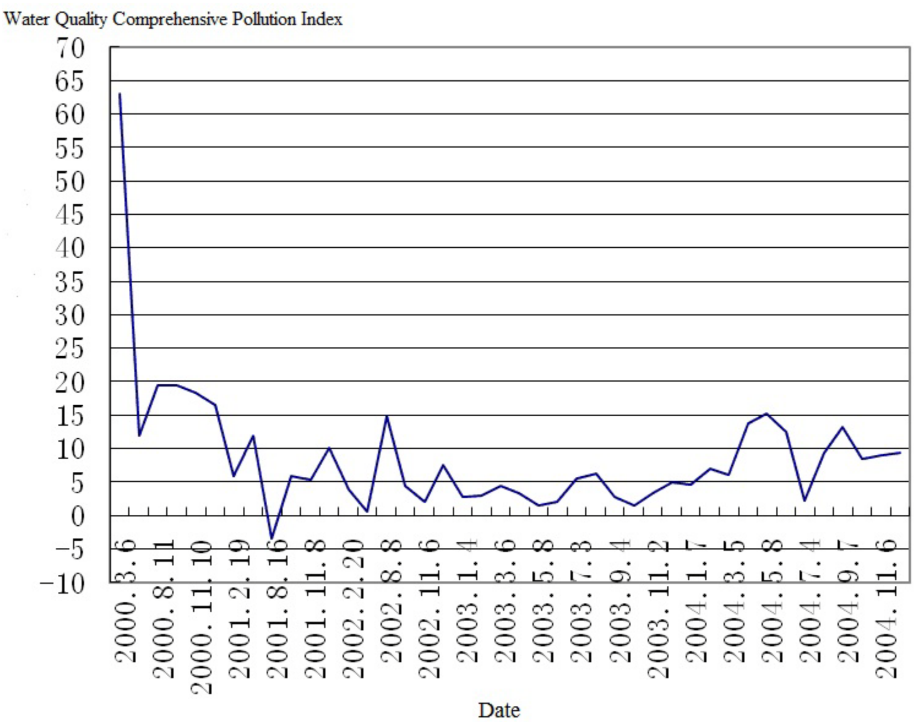


Figure 2. Huxin Monitoring Site Water Quality Index with the Change of Time

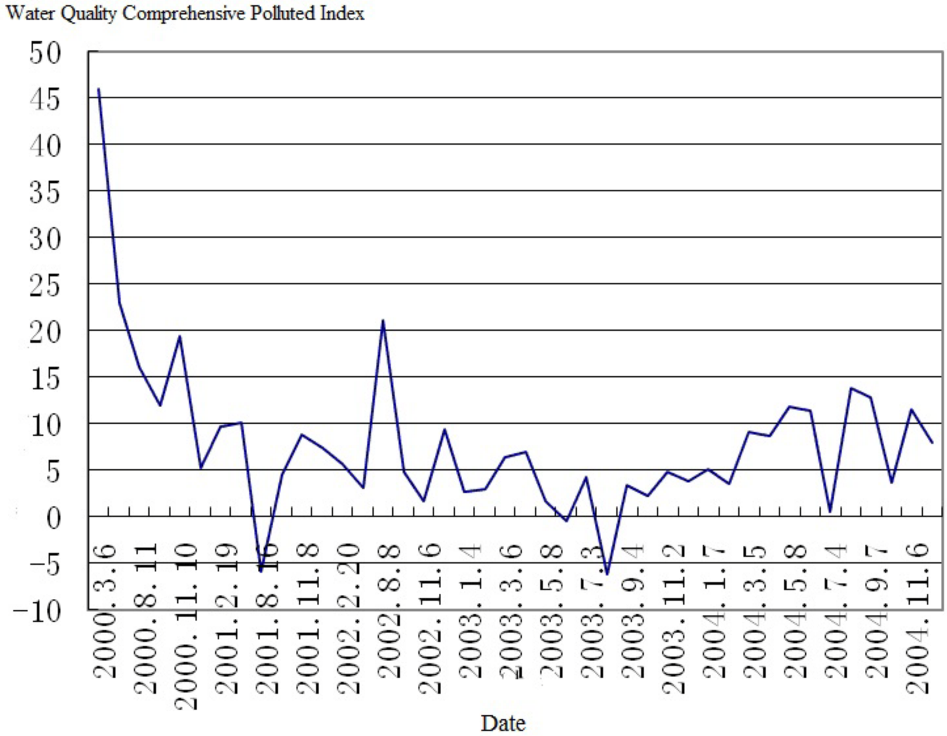
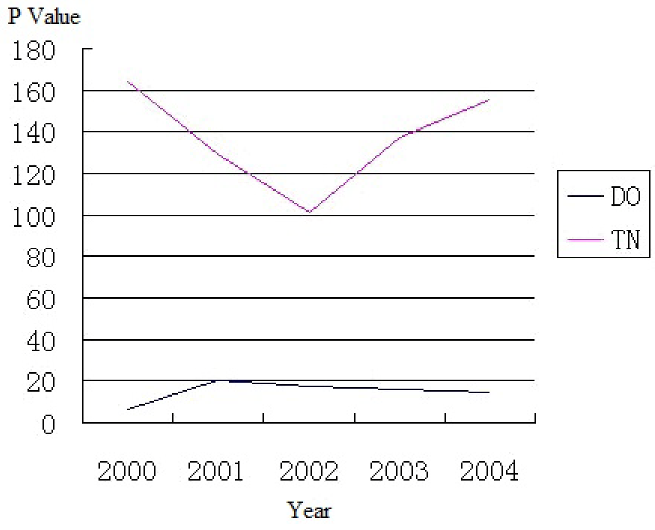


Figure 3. Huguan Monitoring Site Water Quality Index with the Change of Time

For the three monitoring sites, dissolved oxygen (DO) in lakes reaches I and II categories, but not III category. It indicates that the amount of organic pollutants, reductive substances, and algae is not high. For COD, the water in three monitoring sites all reach I category. For BOD, the majority reaches III and IV category, showing that most of organic pollutants in the lake are biodegradable creatures, probably because of living sewage. NH_3-N: it reaches the standard of V and Interior V category, indicating that the lake has been severely eutrophicated.

2.2 Evaluation of Water Quality

Figure 3-4 The Change of P Value of Annual DO, TN



This figure shows that P value of TN is much larger than 5, indicating that TN of Qilu Lake greatly exceeds, dissolved oxygen of water system decreases, and the lake eutrophication has become serious.

Comprehensive index clearly exceeds 1.0 threshold. Multiple indexes exceed corresponding standard values. It indicates that water system functions have been restricted. In order to fully exert water system functions, it is necessary to take engineering and non-engineering measures. It also presents that the P value of TN in 2002 has been decreased. Indeed, it has been taken to prevent the lake eutrophication in 2002. However, it becomes more serious, because industry and animal husbandry have been greatly developed due to fast economic development since 2002.

3. SUGGESTIONS ABOUT RELEVANT ENVIRONMENTAL PLANNING AND MANAGEMENT

3.1 Engineering Measures

It includes mining sediment deposits, deep water aeration, water injection and dilution, and plastic placement on the sediment surface. In addition, for some area, low concentration of phosphorus and nitrogen can be put into lakes, in order to dilute the concentration of eutrophication.

3.2 Chemical Measures

It contains condensing subsidence and chemical algaecide methods. For example, we can put aluminum salt into lakes to condense phosphate to make improvement of the water quality. Additionally, if we use chemical algaecide method, phosphorus will be released after algae decompose. In this case, two measures can be taken: the dead algae should be taken out; or, a certain amount of chemicals should be put into lakes, so that the released phosphate can be condensed.

3.3 Biological Measures

It includes the usage of aquatic organisms to absorb nitrogen and phosphorus nutrients. Nowadays, several countries have started to make experiments by using large aquatic plants as sewage disposal system to purify eutrophic water system. About large aquatic plants, they are eichhornia crassipes, reed, typha angustifolia, Canada Jairo, multi-spike myriophyllum spicatum, nitella, pennywort, and so on. They can be planted depending on different climates and pollutants. To purify sewage, these large aquatic plants, as dominant role, collaborate with other plants and root-zone microbes, through direct plant absorption, microbial transformation, physical absorption and sedimentation to remove nitrogen, phosphorus and suspended particles, and meanwhile elements of heavy metal decomposition. Normally, aquatic plants grow very fast. After harvest, they can be made into fuel, fodder, or even biogas through fermented – so far, this is one of significant measures to control eutrophicated lakes in the world. Recently, some countries adopt biological measures and obtained apparent results. For instance, biological measures have been taken in Germany. The water quality of an artificial lake (with an average depth of 7 m) has been significantly improved. Every year, carnivorous species, such as pike and perch, have been placed into the lake to eat small fishes of zooplankton. Afterwards, such fishes have been largely decreased; meanwhile other species of zooplankton (e.g. cladoceran) have been increased, and accordingly phytoplankton, as food of cladoceran, has been increased. Therefore, several changes have been made, including transparency of the water has been enhanced, bacteria have been decreased, and the depth distribution of oxygen balance has been improved. However, phytoplankton species have been changed; for example, the growth ratio of blue-green algae has been increased, because they cannot be eaten by zooplankton. To resolve the problem, silver carp can be placed into the lake to control the growth of blue-green algae.

3.4 Comprehensive Water Quality Index Analysis and Recommendations

One source of dissolved oxygen is that oxygen penetrates into water when dissolved oxygen does not saturate in water. And the other source is that aquatic plants release oxygen through photosynthesis. Except that dissolved oxygen is generally consumed by sulfide, nitrite, ferrous iron, and reductive substances in water, it is also consumed because of respiration by microbe in water and oxygenolysis by aerobic microbe. Therefore, dissolved oxygen is elementary foundation and representative of self-purification capacity of water. When dissolved oxygen saturation in water is closed to 9ppm, and algae strongly proliferate, the volume of dissolved oxygen in water has been decreased. The volume of dissolved oxygen can be decreased when water is polluted by organics and reductive substances. For aquaculture industry, dissolved oxygen in water has significant effect on the existence of aquatic creatures such as fishes. When the volume of dissolved oxygen is lower than 4 mg/L, it will leads to the death of fishes because of suffocation. For human being, the volume of dissolved oxygen in healthy drinking water needs to be at least larger than 6 mg/L. When the consumption ratio of dissolved oxygen (DO) is larger than the ratio that oxygen penetrates into water, the volume of dissolved oxygen can be closed to 0. Correspondingly, anaerobic bacteria can proliferate to deteriorate water. In this respect, the volume of dissolved oxygen in water represents the level of water pollution, especially the level of organic pollution. In this sense, it is one of important indicators showing the level of water pollution, as well as one of comprehensive indictors of water quality. As a result, it is important to monitor the volume of dissolved oxygen because it has great impact on environmental control and aquaculture development. For the issues of COD and BOD treatment, they can be resolved once sewage is drained into lakes after treatment, or artificial wetlands are established between residential areas and lakes to decrease organic pollutants to flow into lakes. The formation of NH_3-N is probably because human and animal excreta are drained into lakes without any treatments. (It is unstable of organic nitrogen in human and animal excreta, because it can easily decompose into ammonia.) Two of significant sources of ammonia are storm runoff and the loss of agricultural fertilizers. Ammonia nitrogen also comes from industrial sewage caused by chemistry, metallurgy, petrochemical, paint pigments, gas, coke, tanning, fertilizer, etc. Therefore, we recommend that flood irrigation method can not be adopted in agriculture. If adopted, it will easily lead to the loss of N element in farmlands, and make it exceed standard values to form water eutrophication in surround lakes. It is necessary to control the sewage of chemical plants around lakes, in order to prevent sewage to flow into the lakes and form pollution. Living sewage also needs to be treated and then flow into lakes.

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