Temporal and Spatial Variation of water quality in the Yongding River Basin

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Abstract: For exploring the water quality and macroinvertebrate community characteristics of the Yongding River Basin, investigation of water environment and macroinvertebrates was conducted in 34 sampling sites in August 2016 and April 2017. Furthermore, Water Quality Index (WQI) and biological index (BI) were used to assess the water quality of studied rivers. According to the water quality evaluation results of the WQI and the BI method, the water quality of most sites in non-flood season were equal to or better than those in flood season, and these sites were mostly located in urban area. The dominant land use and non-point source pollution was the primary contributor to water quality degradation in rural areas. There are both similarities and differences between BI index and water quality identification index. From the evaluation results of Sanggan River, Yanghe River and Yongding River, the water quality of Yanghe River is better than that of Sanggan River and Yongding River.

1. INTRODUCTION

Biological monitoring of water quality is to monitor the response of organisms to pollutants, that is, to analyze and judge the nature of water pollution by studying the toxicological, physiological and biochemical reactions of individual aquatic organisms, the number of species, the composition of community structure, and the function of aquatic ecosystems. Aquatic organisms are widely distributed, and many groups are sensitive to changes in the water environment. The use of aquatic organisms for water quality biological monitoring has many incomparable advantages in chemical monitoring: (1) It can comprehensively reflect the environmental quality status and interact with various pollution factors; (2) It has the function of continuous monitoring, which can reflect the cumulative effect of pollutants, and is a long-term and historical reflection of the environmental quality; (3) Point source pollution, Sewage treatment plants and non-point source pollution are very sensitive to the impact of water quality; (4) Economical and highly sensitive. Biological monitoring does not require expensive equipment, and

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the indicator species is very sensitive to certain pollutants. The organisms used for biological evaluation include bacteria, zooplankton, algae, higher aquatic plants, fish, and macrobenthic invertebrates. At present, macrobenthic invertebrates are the most widely used in water quality biological assessment. They are closely related to their long life cycle, relatively fixed living place, sensitivity to water quality changes, large individuals and easy collection and identification. The environmental departments of the countries that carry out water quality biological monitoring all over the world include benthos indicators as mandatory items into the environmental monitoring specifications. As the main group of macrobenthic invertebrates, aquatic insects often account for 65-95% of the total number of benthic invertebrates.

Biotic index index (BI) is a numerical value that can express the quality of water environment, which is established by using the type and quantity of indicator organisms in water bodies and the sensitivity to water pollution. The pollution tolerance of benthic animals is the tolerance of organisms to various external pollution factors, so the BI index can be used to evaluate the changes in water quality caused by various pollution factors. The advantages of the BI index include: considering both the pollution tolerance of benthic animals and the species diversity of benthic animals; the BI index can ignore the impact of occasional species, and accurately count the species information of benthic animals; the BI index Simple calculation and strong operability. Since the pollution tolerance of the same species of benthic animals in different regions may have certain differences, it is required to make appropriate adjustments to the pollution tolerance value of the benthic animals in the process of applying and promoting the Biological Index.

2. METHODS AND MATERIALS

2.1 Study area

The Yongding River Basin is located between 112°43′ and 117°42′ east longitude, and 39°07′ to 40°56′ north latitude. The Yongding River 747 km, it is the longest tributary of the Haihe River. And it covers an area of 47,000 km², of which 60% is mountainous. The Sanggan River and the Yang River are major water source for agriculture and industrial activities located in upstream area[2]. Beijing and Tianjin are located in the downstream, an area with developed agriculture and industries [3].

There are 34 sampling sites of the upstream of Yongding River Basin in non-flood season (April 26 to May 23) and flood season (August 10 to September 2) from 2016 to 2017 (Figure 1). Specifically, eleven sites were located in the Sanggan River (M1 to M11), eleven were located in the Yang River (M12 to M22), and eleven were located in the Yongding River and Yongdingxinxin River (M23 to M33). Yongding River Bridge (M27) was dried up and no samples were collected.

![Figure 1 Sampling sites in the Yongding River Basin](image-url)
2.2 Sampling and monitoring data

2.2.1 Physiochemical variables
Dissolved oxygen (DO) was measured in sites using a YSI 650 Multiparameter Display System (YSI Inc., Yellow Springs, OH, USA). Calibration of sensors was performed before each survey. Ammonia nitrogen (NH₄-N), permanganate index (CODₘn), chemical oxygen demand (COD), five-day biochemical oxygen demand (BOD₅), total phosphorus (TP), total nitrogen (TN), were measured according to standard methods of the American Public Health Association [5]. The concentrations of the heavy metal elements, such as arsenic (As), mercury (Hg), cadmium (Cd), chromium (Cr⁶⁺), and lead (Pb) were determined using an Agilent 7500a ICP-MS (Agilent Technologies, USA).

2.2.2 Benthic invertebrate assemblages
In this study, macroinvertebrates were qualitatively and quantitatively sampled in each site using a Surber sampler. Three replicates were collected randomly at each site in this study. All samples were preserved in 70% ethanol in the field, and were sorted, counted, and identified to species or genus in the laboratory.

3. Method

3.1 CCME Water Quality Index (CCME WQI)
The CCME Water Quality Index (CCME WQI) provides a convenient means of summarizing complex water quality data and facilitating its communication to a general audience. The index produces a number between 0 (worst water quality) and 100 (best water quality). These numbers are divided into five descriptive categories to simplify presentation. For details, see the paper of “Spatio-temporal variation analysis of hydrochemical characteristics in the Luanhe River Basin, China” [6].

The classification basis and the corresponding comprehensive water quality grades were: 95≤CCMEWQI≤100, Excellent; 80≤CCMEWQI <95, Good; 65≤CCMEWQI<80, Fair; 45≤CCMEWQI<65, Marginal; 0≤CCMEWQI<45, Poor.

3.2 Biotic Index (BI)
Biotic Index is a scale for showing the quality of an environment by indicating the types of organisms present in it. It is often used to assess the water quality in rivers. It is measured from 1 to 10 and corresponds to the seven degrees.
The calculation formula of BI index is:

\[ BI = \sum_{i=1}^{S} \frac{a_i n_i}{N} \]

As, n,—the number of individuals in the classification unit (genus or species) of i-th;
a_i—Stain resistance value of the classification unit (genus or species) of i-th;
N—The sum of individuals of each unit (genus or species);
S—Number of species.

BI=0.00~3.50, Excellent; 3.51~4.50, Very Good; 4.51~5.5, Good; 5.51~6.50, Fair; 6.51~7.50, Fairly Poor; 7.51~8.50, Poor; 8.51~10.00, Very Poor.

4. RESULTS AND DISCUSSION

4.1 Hydro-chemical evaluation of surface water quality in the YRB
According to the national surface water quality standards of China (GB3838-2002), we used classes I as the guidelines, the standard for each parameter was DO≥7.5, NH₄-N≤0.15mg/L, CODₘn≤2mgO₂/L, BOD₅≤3mg/L, COD≤15mg/L, TP≤0.02mg/L, TN≤0.2mg/L, As≤0.05mg/L, Hg≤0.0005mg/L, Cd≤0.001mg/L, Cr⁶⁺≤0.01mg/L, Pb≤0.01mg/L.
The results of CCME WQI showed that 13#, 14#, 17# and 19# had the best water quality in the Yongding River Basin which were located in Yang River, the main reason was that the Yanghe River flows through some cities and urban sewage is the main source of pollution. And 4#, 5#, 6# and 8# were seriously polluted. And water quality scores had distinct difference between the non-flood season and flood season; the pollution levels of most sites in flood season were equal to or higher than those in non-flood season, such as sites 2#, 3#, 4#, 5#, 6#, 7#, 9#, 10#, 11#, 12#, 14#, 16#, 17#, 18#, 22#, 23#, 24#, 25#, 28#, 29#, 30#, 31#, 32#, 33#, 34#. The main reason may be that these sites were mostly located in rural areas, and non-point source pollution in agriculture land was the primary contributor to water quality degradation. The pollution levels of 1#, 8#, 13#, 19#, 20#, 21# and 26# in flood season were lower than in non-flood season. The main reason for which cause this phenomenon is that these sites are located near a town, so point source emissions are the main source of pollution, the increased rainfall plays a role in dilution of pollutants in the river in flood season.

4.2 Biological distribution in the YRB

There are 50 species of benthic animals in the Yongding River Basin, belonging to 3 subjects, 5 classes, 25 families. Among them, There are 2 classes, 4 families and 6 species in the phylum Annelida, accounting for 12% of the total; 1 class, 4 families and 4 species in Mollusca, accounting for 8% of the total; 2 classes, 17 families, and 40 species in the phylum Arthropod, of which 37 species, 14 families are in the Insecta, accounting for 74% of the total, and there are 3 families, 3 species in the Crustacea, accounting for 6% of the total. The average abundance of benthic animals is 239 ind/m². The abundance ranged from 0 to 2212.5 ind/m², the average biomass was 2.533 g/m², and the biomass ranged from 0 to 14.437 g/m².
According to the BI pollution level judgment standard and the BI value calculation results of each station, except for individual points, the BI value in the flood season is generally lower than that in the non-flood season. However, similar to the results calculated by WQI, the water quality of the Yanghe River is better than that of the other two rivers. Except for a few stations, the BI calculation results for flood season and non-flood season are roughly the same as the WQI calculation results, that is to say, the BI value of most stations during the flood season is lower than that in non-flood season, so the water quality is relatively good.

Figure 4 The value of BI

5. Conclusion
Biological assessment of water quality is the method to the assessment of biological quality of water through the investigation or direct detection of aquatic organisms[7]. In this paper, the water quality identification index and benthos BI index are used to evaluate the water quality of Yongding River Basin, and also evaluate the accuracy of Bi index in water quality assessment. The results showed that the water quality of Sanggan River and Yanghe River is mild to moderate pollution, and the main stream of Yongding River is moderate to severe pollution. There are both similarities and differences between BI index and water quality identification index. From the evaluation results of Sanggan River, Yanghe River and Yongding River, the water quality of Yanghe River is better than that of Sanggan River and Yongding River. The Bi index of the main stream of Yongding River is higher, which indicates that The Bi index considers both species diversity and its perspective of benthos[8], and the sensitivity of benthos in this river is lower than that in the other two rivers, and the tolerance is relatively high. The benthos move slowly, live in a fixed place, and escape from adversity is slow. This is consistent with the water quality results reflected by the water quality index. Therefore, the biological evaluation of river water quality combines the biological index evaluation with water environmental parameters, which can reflect the water quality of the basin more comprehensively and reliably.

Acknowledgements
This study was supported by the major Science and Technology Program for Water Pollution Control and Treatment (2018ZX07101005)

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