Construction of Urban Water Ecological Civilization System

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Abstract. To explore the relationship between water ecological civilization construction and urban water ecosystem health, the Water-Human-Health (WHH) evaluation model that could reflect the health connotation and mechanism of urban water ecosystem model was constructed to evaluate the health level of urban water ecological system. The result showed that the health status of urban water ecosystem health in X city during 2005~2013 was evaluated and it was found that the index of the urban water ecosystem health showed fluctuating upward trend, water system health index declined slightly in fluctuation and the human system health index increased steadily. To sum up, the urban water ecosystem health assessment method and urban water ecological civilization construction framework are reasonable and feasible.

1. Introduction

Water is an indispensable key element in the ecological environment, and the construction of water ecological civilization is an important content of the construction of ecological civilization. At present, the construction of water ecological civilization is one of the hot topics in China. Many local governments are carrying out the construction of national or provincial pilot cities, and many experts and scholars have done a lot of related researches. The reason is that there are many water problems in China, and the new idea of the construction of water ecological civilization is one of the new ways to solve the water problem. Specifically, to promote the construction of ecological civilization is the urgent need to ease the contradiction between China's economic and social development and water resources and environmental protection and promote the harmonious development of human and water; it is the urgent need to alleviate people's "water anxiety" and improve the Party's ruling ability and level; it is also the urgent need to accelerate the overall pace of the construction of ecological civilization and realize the sustainable development of China. Therefore, it is urgent to find out the overall idea of the construction of urban water ecological civilization in the future for promoting the smooth implementation of the construction of water ecological civilization.

2. Research status at home and abroad

The study of ecosystem health in foreign countries has a long history. The earliest and closest concept was the "natural health" [1], which was first proposed by the famous ecologist James Hutton. In 1989, Rapport used the appropriate urban development goals to measure the status and performance of the urban ecosystem. He pointed out that the urban ecosystem should not only maintain the internal circulation of the ecosystem itself, but also meet the reasonable requirements of human society so that
it could be called healthy [2]. At this point, the health of the ecosystem has become a hot topic. The IDRC project further studied its connotation and Colin pointed out that the urban ecosystem was the sum of complex relationship of interaction between human beings and their surrounding environment [3]. Therefore, the healthy urban ecosystem means not only natural - artificial binary ecosystem health and integrity, but also includes the city residents' health and health of the development of the whole society [4]. With further research, Hancock and other experts conducted a detailed summary of the urban ecosystem health connotation from 6 aspects, including the residents, living environment, social development, biological species, natural environment and natural ecological system, which reflected the sustainable development of urban ecosystem [5].

There are many studies on the health of urban aquatic ecosystem, but the direct research achievements are rare. Most of them focus on the research of water ecosystem health instead of exploring the specific system of the city, but the indirect results are many. In the most important aspect of healthy operation mechanism, similar research results that can be used for reference can be summarized into three categories: the first category is analogy of human health physiological function. Through the source and sink, and for self-regulating recovery ability and external means, it maintains the overall health of the system [6]; secondly, the model of pressure - state – response model is used to analyse the overall healthy operation mechanism of the system; thirdly, the natural water cycle is applied to characterize the water ecosystem, the social water cycle is adopted to characterize the city human activities and analyse the system healthy operation mechanism under nature - society binary water cycle.

3. Health evaluation of urban water ecosystem

3.1. Health evaluation model of urban water ecosystem

This paper discusses the health evaluation model of urban water ecosystem based on the model of ecosystem health assessment at home and abroad. There are three main categories:

The first category is the PSR model and a series of relevant models derived of driving force - state - response model and driving force - pressure – state – exposure – impact - response model. It emphasizes the organic unity of water resources and environmental protection and economic and social development in the role of urban water ecosystem complexity and vulnerability. It also reflects the interaction and causal relationship between people and the various factors in the system.

The second category is the evaluation model based on the framework of nature - economy - society (NSE) complex ecosystem. Based on the composition of urban water ecosystem, the model constructs the health evaluation index system of urban water ecosystem from three aspects: nature (water resources environment), economy and society, and the corresponding evaluation are carried out. The method of selecting indicators is more subjective.

The third category is the evaluation model based on the health connotation of urban water ecosystem and the characteristics of specific evaluation object. Based on the health connotation of different ecosystems, the model finds out the important interaction factors in the healthy operation of the system, and builds corresponding evaluation models combined with the characteristics of the system.

In this paper, the third kind of health evaluation model construction method is adopted taking into consideration the health connotation of urban water ecosystem and its clear health operation mechanism. In full consideration of the concept of hierarchy, space-time theory, city ecology theory, systematic ecology theory and other related evaluation theories, according to the interpretation of urban water ecosystem and urban water ecosystem health and analysis of the healthy operation mechanism of urban water ecosystem, it can be seen that under the guidance of water ecological civilization concept, for urban water ecological system, the health level is mainly the mutually acting and influencing relation evolution of water system and human system two subsystems. On the one hand, it takes optimizing human various wading activities as the foundation; on the other hand, it regards achieving sustainable water supply ecological products as the goal. Therefore, Water-Human-
Health (WHH) evaluation model, which can reflect the connotation of urban water ecosystem health, is built to evaluate the health level of urban water ecosystem.

Based on the WHH evaluation model, the health evaluation index system of urban water ecosystem is constructed, and the fuzzy matter element method based on Hamming approach is applied to evaluate its health level.

The framework schematic of the WHH evaluation model is shown in Figure 1.

![Framework schematic of WHH evaluation model](image)

**Figure 1.** Framework schematic of WHH evaluation model.

### 3.2. Health evaluation method of urban water ecosystem

The dimension of each index is different, so it will give the inconvenience for the subsequent evaluation process. As a result, before calculating the weight and the specific evaluation, we need to make standardization processing of original data.

The evaluation index can be divided into three categories: positive index, reverse index and intermediate excellent index. Among them, for the positive index, the index value showed a positive correlation with the urban water ecosystem health level, such as the amount of water resources per capita and green coverage rate; in terms of reverse index, the value of index is negatively correlated with urban water ecosystem health, such as population density and per capita water consumption; form the perspective of intermediate index, the value of index, in a small range where the urban water ecosystem health level is the optimal, is lower or higher than the range and the health degree becomes weak. Because of the reasons for the length of the sequence, we think that the indexes are positive index or reverse index. The following standardized formulas (1), (2) and (3) are respectively adopted for calculation for different types of indexes.

\[
Y_{ij} = \frac{X_{ij} - X_{i\min}}{X_{i\max} - X_{i\min}}
\]  

(1)
In the formula, \( x_{\text{imax}}, x_{\text{imin}}, \) and \( x_i \) are the maximum, minimum and average values of all samples in the same index. \( y_{ij} \) indicates the value after standardization, which is between 0 and 1.

In the statistical theory and practice, the weight is the number that indicates the importance of each evaluation index. In the process of evaluating the system through the index system, we usually use weight to reflect the importance of each index. The commonly used weight determination method has two kinds: one is the subjective weighting method, mainly through the decision maker's experience for weight each index and reflecting the experts and decision makers willingness, which is of great subjectivity; the other is objective weighting method, which conducts automatic weighting to indicators according to the objective law of indicators of the actual data, but may not well highlight the features of the evaluation target. Here, combining the advantages of the two methods, we choose the combination of subjective and objective methods to weight.

4. Results and discussion

4.1. Evaluation of the health status of urban water ecosystem

Based on the calculation results of the urban water ecosystem health in zoning during 2005–2013, the change trend maps of UWEHI and WSHI and HSHI in each calculation area during 2008–2016 were obtained. The change trend of the health evaluation results of urban water ecosystem in XX city is shown in Figure 2.

\[
y_{ij} = \frac{x_{\text{imax}} - x_{ij}}{x_{\text{max}} - x_{\text{min}}} \\
y_{ij} = 1 - \frac{\max_{i=1, n} |x_i - x_{ij}|}{\overline{x}_i - x_{ij}}
\]
ecological system, we can see that the influence difference between the two is not too big, but the human system is slightly higher than that in water system. The change trend of UWEHI is closer to that of HSHI, which just coincides with the actual situation of X city. As a pioneer area of ecological civilization, X city has good natural resources, but its economy is under development. And its social development and human activities are still in the state of not disrupting the normal operation of the water system. Both of them play a role in the health of urban water ecosystem. With the continuous development of the economy and society, the influence of the humanities system on the urban water ecosystem is also rising. Combined with the stress of human activities on water system and the promotion of science and technology management level to the water system, the influence of the humanities system is further increased.

4.2. Evaluation of health factors of urban water ecosystem
In the water system and human system as the research object, we adopt fuzzy matter-element model based on Hamming approach degree to obtain the contribution values of water system and human system different field layers to the health level of the subsystems, namely the field level health index, including water resource status (WRS), ecological environment condition (EEC), economic and social development level (ESDL) and utilization of water resource and management level (UWML). The comparison of subsystem field health index in XX city in 2008~2016 is shown in Figure 3.

![Figure 3. Comparison of subsystem field health index in XX city during 2008–2016.](image)

As a whole, in the past 10 years, there have been great changes in the 4 fields of X, including WRS, EEC, ESDL and UWML. Health status, from large to small, has changed from WRS, EEC, ESDL and UWML in 2008 to EEC, ESDL, WRS and UWML in 2016. EEC and ESDL are almost the same and WRS and UWML are almost the same.

5. Conclusion
In this paper, under the guidance of the concept of water ecological civilization and water ecological civilization construction theory system, the concept and connotation of urban water ecosystem health as well as the urban water ecosystem health operation mechanism were analyzed. According to the analysis of the healthy operating mechanism of urban water ecosystem, the health situation was considered as the relation evolution of the interaction between water system and human system two
systems, so as to construct the WHH evaluation model. In addition, the water ecosystem health status in X city of 2005~2013 was evaluated. The results showed that the index of urban water ecosystem health showed fluctuating upward trend, water system health index declined slightly in fluctuation and the human system health index increased steadily. To sum up, the water system health status of overall X city and administrative units is better than that of the human system.

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