International Journal of Scientific Research and Management (IJSRM)
||Volume||10||Issue||11||Pages||C-2022-63-73||2022||
Website: www.ijsrm.in ISSN (e): 2321-3418
DOI: 10.18535/ijsrm/v10i11.C01

Application of Partial Connection Number and Subtraction Set Pair Potential in Evaluation of Development Trend of Water Environment Bearing State

[1]Zhi jie Yu, [2]Fan xiu Li*

[1,2]College of Chemistry and Environmental Engineering, Yangtze University, Jingzhou Hubei, 434023, China

Abstract
Aiming at the uncertainty between the evaluation samples and the evaluation standards in the evaluation of water environment carrying capacity, a five-element connection coefficient evaluation model for water environment carrying capacity based on the set pair analysis theory is constructed, and the partial connection coefficient method and the subtractive set pair potential method are used. The development trend of the water environment carrying state was analyzed, and the method was used in the dynamic evaluation of the water environment carrying capacity in HJ City. The results show that the water environment carrying capacity of HJ city in 2015-2021 is between grades IV and III, and the water environment carrying capacity is poor, but the overall potential is developing from partial antipodal to homogeneous, showing a development trend for the better. According to the comprehensive index evaluation results, targeted suggestions for improving the water environment carrying capacity are put forward. From the analysis, it can be seen that the above dynamic evaluation and analysis results are reasonable and reliable, and the method is intuitive and simple, which can provide a reference basis for the improvement of regional water environment quality.

Keywords : Water environment carrying capacity; set pair analysis; quintuple connection number; partial connection number; subtractive set pair potentia.

1. Introduction

Population expansion, resource shortage and environmental pollution are the three major problems and challenges facing the world today [1], among which water environmental pollution and its prevention and control have attracted widespread attention in recent years, and many countries and regions have especially set up major science and technology projects for water pollution control and treatment to deal with the problem of water environmental pollution.

The water environment carrying capacity is an important method to study the degree of water pollution and an important basis to determine the economic benefits, which is of great significance to achieve the coordinated development of regional water environmental protection and economy. The water environment carrying capacity is the maximum limit of pollutants that can be accommodated in a certain range of waters through self-purification and regulation to maintain good ecological environment conditions [2]. With the continuous research, the water environment carrying capacity evaluation method has developed from the single indicator and static analysis in the past to the current dynamic and comprehensive evaluation of multiple indicators.

Chen Wenting et al. constructed a water environment carrying capacity evaluation index system based on coupled DPSR model and time difference analysis method, and combined neural network and fuzzy mathematics to construct a T-S fuzzy neural network model to evaluate the water environment carrying capacity of Baiyangdian watershed [9].Based on the conceptual model of PSDRDP, Wang Bin et al. constructed a model containing three pairs of interactions: "pressure-support force", "destructive force-recovery force" and "degradation force-improvement force". The evaluation index system of Guizhou's resource and environment carrying capacity is based on the PSDRDP conceptual model, and the TOPSIS method is used to evaluate the level of Guizhou's water and environment carrying capacity by assigning weights through the entropy value method [10].Liu et al. constructed an evaluation index system covering water resources, social economy and ecological environment, measured the weights of each index through the AHP method, and introduced the logistic logarithmic carrying capacity model to make a comprehensive evaluation of the water environment carrying capacity of Yichang City [11].

The above research results carried out the construction of the water environment carrying capacity index system and the quantitative evaluation of the regional water resources carrying capacity level from different perspectives, which enriched the theoretical system and evaluation analysis framework of the water environment carrying capacity, however, the dynamic analysis of the water environment carrying capacity system and its development trend could not be accurately judged. In fact, the water environment carrying capacity is a contrasting concept, and the boundary between two adjacent levels is not clear. The set-pair analysis method proposed by Mr. Zhao Keqin provides an effective solution to this kind of problem.

This study takes into account the many uncertainties in the water environment carrying capacity system, and constructs a water environment carrying capacity evaluation model based on the partial linkage and subtractive set-pair potential theory in the set-pair analysis method, and explores the dynamic evolution of the relationship structure of the set-pair system at the micro level, so as to identify the dynamics of the water resources carrying capacity system, which provides a new effective way for the dynamic analysis of the water environment carrying capacity system and the judgment of its development trend.

2. Methodology

2.1 Set pair analysis and connection number

Set pair analysis (SPA) is a mathematical method of connection proposed by Chinese scholar Mr. Zhao Keqin in 1989 [12], which integrates the certainty and uncertainty of a problem into a unified conclusion, and can study the intrinsic relationship between the elements of a system and the whole system. The connection number is a basic tool for set pair analysis to deal with problems. Set pair analysis quantifies the characteristics of two sets from three perspectives: identity, dissimilarity and inverse, and the expression for the connection number [13] is as follow：

$$\begin{cases} u = \frac{S}{N} + \frac{F}{N} i + \frac{P}{N} j \\ N = S + F + P \end{cases} \quad (1)$$

In equation (1) N is the total number of characteristics contained in the two sets; S is the number of characteristics for which the two sets are identical (identical); F is the number of differentially uncertain characteristics for which the two sets are neither identical nor opposed (dissimilar); P is the number of characteristics for which the two sets are opposed to each other (inverse); j is the coefficient of opposition, designated as -1; i is the coefficient of difference and is an uncertain value between -1 and 1 depending on the circumstances.

In equation (1) let a = S/N, b = F/N and c = P/N. The expression for the number of connection can then be simplified to the three-element connection number:

$$\begin{cases} u = a + bi + cj \\ a + b + c = 1 \end{cases} \quad (2)$$

In equation (2), a is the same component; b is the difference component; c is the opposition component.

Among the variance components b, there is a same component and a opposition component, which can be refined and expanded to increase the number of elements in the connection number. The expressions for the five-elements of the connection number are constructed by dividing the object of study into "same, partial same,different, partial opposite, and opposite ", which is as follows:

$$\begin{cases} u = a + b_1 i_1 + b_2 i_2 + b_3 i_3 + cj \\ a + b_1 + b_2 + b_3 + c = 1 \end{cases} \quad (3)$$

Where, $a,b_1,b_2,b_3,c \in [0,1]$ and $a+b_1+b_2+b_3+c=1$.

2.2 Construction of a model for evaluating the carrying state of the water environment based on the five-element connection number.

Water environment carrying state is the overall situation of social, economic and ecological environment carried by water environment system under certain regional and social scale. According to the regional water resources index, water ecology index, water environment index combined with expert consultation, literature research and other methods, to establish the regional water environment bearing capacity evaluation index system, this paper will be divided into five levels of water environment bearing status, I level for surplus bearing, II level for safe bearing, III level for critical bearing, IV level for slight overload, V level for serious overload. According to the characteristics of water environment carrying capacity, assessment indexes are generally divided into two categories, one of which is the smaller the assessment index, the better the assessment level, i.e. cost-type index. The other is that the smaller the evaluation index is, the worse the evaluation level is, i.e. the benefit-type index.

If the index is a benefit-type index, the computational equations of u are as follows:

$$u = \begin{cases} 1 + 0i_1 + 0i_2 + 0i_3 + 0j, x \ge s_1 \\ \dfrac{s_1 + s_2 - 2x}{s_2 - s_1} + \dfrac{2x - 2s_1}{s_2 - s_1} i_1 + 0i_2 + 0i_3 + 0j, \dfrac{s_1 + s_2}{2} \le x < s_1 \\ 0 + \dfrac{s_2 + s_3 - 2x}{s_3 - s_1} i_1 + \dfrac{2x - s_1 - s_2}{s_3 - s_1} i_2 + 0i_3 + 0j, \dfrac{s_2 + s_3}{2} \le x < \dfrac{s_1 + s_2}{2} \\ 0 + 0i_1 + \dfrac{s_3 + s_4 - 2x}{s_4 - s_2} i_2 + \dfrac{2x - s_2 - s_3}{s_4 - s_2} i_3 + 0j, \dfrac{s_3 + s_4}{2} \le x < \dfrac{s_2 + s_3}{2} \\ 0 + 0i_1 + \dfrac{s_3 + s_4 - 2x}{s_4 - s_2} i_3 + \dfrac{2x - s_2 - s_3}{s_4 - s_2} j + 0j, s_4 < x < \dfrac{s_3 + s_4}{2} \\ 0 + 0i_1 + 0i_2 + 0i_3 + j, x \le s_4 \end{cases} \quad (4)$$

If the index is a cost-type index, the five-element connection number of water environment carrying capacity evaluation is:

$$u = \begin{cases} 1 + 0i_1 + 0i_2 + 0i_3 + 0j, x \le s_1 \\ \dfrac{s_1 + s_2 - 2x}{s_2 - s_1} + \dfrac{2x - 2s_1}{s_2 - s_1} i_1 + 0i_2 + 0i_3 + 0j, s_1 < x \le \dfrac{s_1 + s_2}{2} \\ 0 + \dfrac{s_2 + s_3 - 2x}{s_3 - s_1} i_1 + \dfrac{2x - s_1 - s_2}{s_3 - s_1} i_2 + 0i_3 + 0j, \dfrac{s_1 + s_2}{2} < x \le \dfrac{s_2 + s_3}{2} \\ 0 + 0i_1 + \dfrac{s_3 + s_4 - 2x}{s_4 - s_2} i_2 + \dfrac{2x - s_2 - s_3}{s_4 - s_2} i_3 + 0j, \dfrac{s_2 + s_3}{2} < x \le \dfrac{s_3 + s_4}{2} \\ 0 + 0i_1 + \dfrac{s_3 + s_4 - 2x}{s_4 - s_2} i_3 + \dfrac{2x - s_2 - s_3}{s_4 - s_2} j + 0j, \dfrac{s_3 + s_4}{2} < x < s_4 \\ 0 + 0i_1 + 0i_2 + 0i_3 + j, x \ge s_4 \end{cases} \quad (5)$$

In equations (4) and (5), s1, s2, s3 and s4 denote the grade boundaries of the evaluation level of each evaluation factor respectively; x is the measured index of the evaluation factor.

2.3 Determination of evaluation index weight

In this paper, subjective analytic hierarchy process (see literature 15 for specific steps) and objective entropic weight method (see literature 16 for specific steps) are used to assign weights. First, the subjective weight ω_1 and objective weight ω_2 of each index are calculated, and then the arithmetic mean value is taken as the final weight ω_t.

2.4 Establishment of the total connection number formula

Establish the set pair of water environment carrying state evaluation objects and evaluation criteria. Let the actual measured value of the evaluation sample of the region in a certain year be the set A and the evaluation criteria be the set B. Then the five-element connection number u[14] of the set pair H(A, B) can be defined as:

$$u=\sum_{t=1}^{m}\omega_t a_t+\sum_{t=1}^{m}\omega_t b_{t,1} i_1+\sum_{t=1}^{m}\omega_t b_{t,2} i_2+\sum_{t=1}^{m}\omega_t b_{t,3} i_3+\sum_{t=1}^{m}\omega_t c_t j \qquad (6)$$

Where, t is the t-th evaluation index; ω_t is the weight of index t; a_t、$b_{t,1}$、$b_{t,2}$、$b_{t,3}$、c_t are the identical degree, the mild discrepancy degree, the moderate discrepancy degree, the severe discrepancy degree and the contrary degree of each index respectively; and j are the coefficients of the mild discrepancy degree, the moderate discrepancy degree, the severe discrepancy degree and the contrary degree of each index respectively.

2.5 Determining the evaluation grade

In this paper, the minimum confidence criterion [17] is used to determine the assessment grade of carrying state of water environment, assuming that the carrying state grade is *k* corresponding to h_k:

$$h_k = f_1 + f_2 + \cdots + f_k > \lambda \quad (k=1,\ 2,\ 3,\ 4,\ 5) \qquad (7)$$

In equation (7), h_k is the sum of the first *k* components of the five-element connection number; f_1, f_2, f_3, f_4 and f_5 are respectively the same degree component, the same degree component, the medium degree component, the opposite degree component and the opposite degree component of the water environment carrying state. $f_1=\sum_{t=1}^{m}\omega_t a_t$, $f_2=\sum_{t=1}^{m}\omega_t b_{t,1} i_1$, $f_3=\sum_{t=1}^{m}\omega_t b_{t,2} i_2$, $f_4=\sum_{t=1}^{m}\omega_t b_{t,3} i_3$, $f_5=\sum_{t=1}^{m}\omega_t c_t j$, λ is the confidence level, generally take [0.5, 0.7], this paper takes 0.5.

2.6Analysis of carrying state of water environment based on partial connection number method.

As an adjoint function of connection number, partial connection number is divided into positive connection number, negative connection number and full partial connection number, which can be calculated step by step from each component of connection number. The essence of partial connection number is to describe the development trend of the research object expressed by the connection number at the current micro level. The partial positive connection number reflects the positive development and change trend of the connection number, the negative connection number reflects the reverse development and change trend of the connection number, and the full partial connection number reflects the comprehensive development trend of the connection number.

For the five-element connection number, the first-order, the second-order, the third-order partial connection number and the fourth-order partial connection number are respectively used to determine the micro-movement trend of the carrying state of the water environment in this area. The fourth-order full partial connection number is greater than 0 which indicates that the carrying state of the water environment in this area is developing positively and the fourth-order full partial connection number is less than 0 which indicates that the carrying state of the water environment in this area is developing negatively. The fourth order full partial connection number equal to 0 indicates that the bearing state of water environment in this area is relatively stable. Reference [19] for specific calculation method.

2.7 Analysis of carrying state of water environment based on subtraction set pair potential model

The essence of pairing potential of subtraction set is to describe the relative certainty state and development trend of the research object expressed by connection number at the current macro expectation level.For the five-element connection number $u=a+b_1 i_1+b_2 i_2+b_3 i_3+cj$ the formula [21] is as follows

$$s_f(u) = (a-c)(1+b_1+b_2+b_3) + 0.5(b_1-b_3)(b_1+b_2+b_3) \quad (8)$$

Where $s_f(u) \in [-1,1]$, in formula (8), it can be divided into five potential levels according to the value:inverse potential means that the development of the event is on the verge of collapse,partial inverse potential indicates that the development of the event is ill conditioned, equilibrium potential indicates that the development of the event is in sub-health, partial direct potential indicates that the event is basically healthy, direct potential indicates that the event is developing healthily. When the subtractive set pair potential of the water environment carrying capacity of the assessed area is in the reverse and partial reverse, it indicates that the water environment status of the area has a deteriorating trend.

3. Case study

According to the physical mechanism of the formation of water environment carrying capacity and referring to the existing research results of water environment carrying capacity evaluation, the regional water environment carrying capacity evaluation index system and evaluation grade standard are established. The subjective analytic hierarchy process and objective entropy weight method are used to determine the index weight [15-16]. The evaluation index grade standard and weight of HJ water environment carrying capacity are determined in Table 1 and Table 2.

Table 1 Evaluation Index Grade Standard of Water Environment Bearing Capacity in HJ City

Subsystems	index	I	II	III	IV	V	Type of indicator
water resources index（A）	(A1)Water resources per capita（m^3）	20000	10000	5000	2000	500	direct
	(A2)Per capita cultivated land area（hm^2）	0.3	0.22	0.1	0.07	0.05	direct
	(A3)Per capita forest area（hm^2）	0.8	0.64	0.4	0.25	0.11	direct
	(A4)Utilization of water resources（%）	100	60	40	20	10	direct
water ecology index（B）	(B1)Water quality in proportion to or better than three categories（%）	100	70	60	50	40	direct
	(B2)Standard rate of water quality of drinking water source（%）	100	98	96	90	70	direct
	(B3)Average water consumption per mu for farmland irrigation（$m3.hm^{-2}$）	15000	9000	7500	6300	4500	direct
	(B4)Forest coverage（%）	100	50	35	20	10	direct
water environment index（C）	(C1)Annual average discharge of waste water（m^3）	10	20	30	40	100	inverse
	(C2)COD discharge load（kt）	0.6	1.2	1.8	2.4	3	inverse
	(C3)Fertilizer load（$kg.hm^{-2}$）	480	630	750	900	1500	inverse
	(C4)Pesticide load（$kg.hm^{-2}$）	0	5	10	20	40	inverse

Table 2 Weights of evaluation indexes of water environment carrying capacity in HJ City

Subsystem index	water resources index（A）				water ecology index（B）				water environment index（C）			
	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4
Subjective Weight ω_1	0.10	0.07	0.06	0.07	0.09	0.08	0.04	0.09	0.12	0.12	0.09	0.07
Objective weight ω_2	0.124	0.066	0.054	0.056	0.084	0.09	0.032	0.094	0.110	0.136	0.088	0.066
Weight ω_t	0.112	0.068	0.057	0.063	0.087	0.085	0.036	0.092	0.115	0.128	0.089	0.068

Table 3 shows the measured data of HJ from 2015 to 2021. The index values of water environment carrying capacity of HJ in each year are derived from the Water Resources Bulletin of HJ from 2015 to 2021 and the Statistical Yearbook of HJ from 2015 to 2021. The correlation coefficient of each index component of HJ city from 2015 to 2021 can be obtained by taking the data of Table 1, Table 2 and Table 3 into the formula (4) and formula (5), the results are shown in Table 4.

Table 3 Measured data of water environment carrying capacity evaluation indicators in HJ City from 2015 to 2021

Subsystems	index	2015	2016	2017	2018	2019	2020	2021
water resources index（A）	(A1)Water resources per capita（m^3）	750	850	950	3500	4500	5000	1998
	(A2)Per capita cultivated land area（hm^2）	0.04	0.04	0.05	0.03	0.03	0.04	0.06
	(A3)Per capita forest area（hm^2）	0.23	0.22	0.26	0.28	0.28	0.29	0.29
	(A4)Utilization of water resources（%）	55	58	59	39	37	35	36
water ecology index（B）	(B1)Water quality in proportion to or better than three categories（%）	43	54	55	57	63	64	68
	(B2)Standard rate of water quality of drinking water source（%）	77	78	80	87	95	98	99
	(B3)Average water consumption per mu for farmland irrigation（m^3/hm^2）	6900	7000	8500	6890	6990	7000	4400
	(B4)Forest coverage（%）	50	52	53	54	56	58	60
water environment index（C）	(C1)Annual average discharge of waste water（m^3）	50	57	59	60	70	87	90

	(C2)COD discharge load（kt）	2.5	2.6	2.8	2.9	2.9	2.8	2.9
	(C3)Fertilizer load（kg. hm^{-2}）	490	497	530	600	620	629	630
	(C4)Pesticide load（kg. hm^{-2}）	55	57	59	58	38	39	40

Table 4 The calculation results of the connection number of each indicator in HJ City from 2015 to 2021

	2015	2016	2017	2018	2019	2020	2021
A1	$0.33i_3+0.67j$	$0.47i_3+0.53j$	$0.60i_3+0.40j$	i_2	$0.25i_1+0.75i_2$	$0.37i_1+0.63i_2$	$0.33i_2+0.67i_3$
A2	j	j	j	j	j	j	i_3
A3	$0.34i_2+0.66i_3$	$0.28i_2+0.72i_3$	$0.55i_2+0.45i_3$	$0.69i_2+0.31i_3$	$0.69i_2+0.31i_3$	$0.76i_2+0.24i_3$	$0.76i_2+0.24i_3$
A4	$0.50+0.50i_1$	$0.80+0.20i_1$	$0.90+0.10i_1$	$0.45i_1+0.55i_2$	$0.35i_1+0.65i_2$	$0.25i_1+0.75i_2$	$0.30i_1+0.70i_2$
B1	$0.60i_3+0.40j$	$0.90i_2+0.10i_3$	i_2	$0.20i_1+0.80i_2$	$0.80i_1+0.20i_2$	$0.90i_1+0.10i_2$	$0.60+0.40i_1$
B2	$0.70i_3+0.30j$	$0.80i_3+0.20j$	i_3	$0.54i_2+0.46i_3$	$0.50i_1+0.50i_2$	1.00	1.00
B3	i_2	$0.07i_1+0.93i_2$	$0.33+0.67i_1$	$0.99i_2+0.01i_3$	$0.07i_1+0.93i_2$	$0.07i_1+0.93i_2$	j
B4	1.00	1.00	1.00	1.00	1.00	1.00	1.00
C1	j	j	j	j	j	j	j
C2	j	j	j	j	j	j	j
C3	$0.87+0.13i_1$	$0.77+0.23i_1$	$0.33+0.67i_1$	$0.67i_1+0.33i_2$	$0.52i_1+0.48i_2$	$0.45i_1+0.55i_2$	$0.44i_1+0.56i_2$
C4	j	j	j	j	j	j	j

The five-element connection number of each index in Table 4 is taken into Formula (6) and the total connection number expression is calculated. The evaluation grade is determined according to the minimum confidence recognition criterion as shown in Table 5.

Table 5 The calculation results and evaluation grades of the expression of the total connection coefficient in HJ City from 2015 to 2021

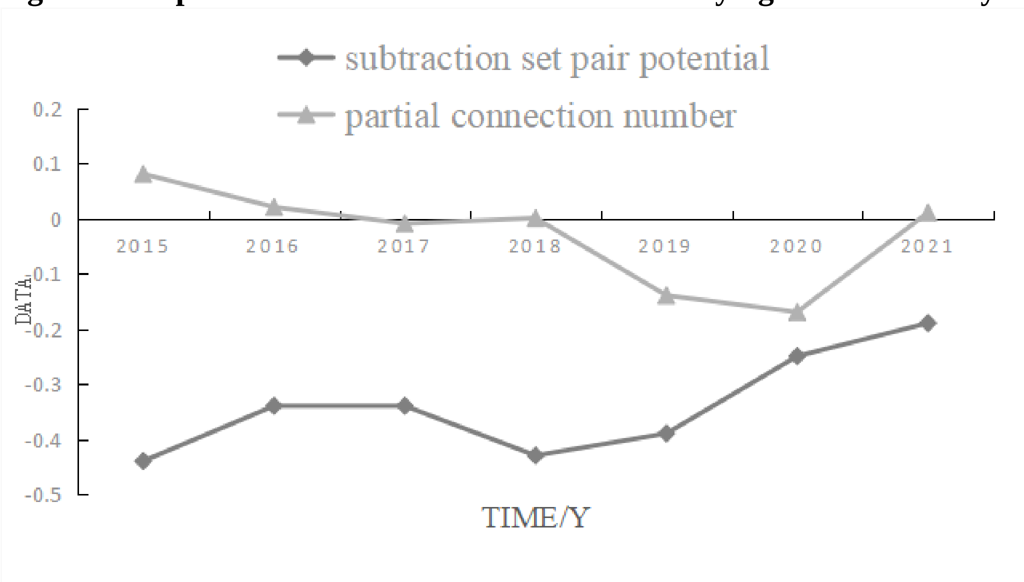
time	total connection degree expression *u*	Evaluation grade
2015	$u_1=0.18+0.03i_1+0.16i_2+0.13i_3+0.50j$	IV
2016	$u_2=0.21+0.04i_1+0.13i_2+0.17i_3+0.45j$	IV
2017	$u_3=0.19+0.09i_1+0.12i_2+0.18i_3+0.42j$	IV
2018	$u_4=0.09+0.10i_1+0.37i_2+0.06i_3+0.38j$	III
2019	$u_5=0.09+0.21i_1+0.30i_2+0.02i_3+0.38j$	III
2020	$u_6=0.18+0.18i_1+0.25i_2+0.01i_3+0.38j$	III
2021	$u_7=0.23+0.09i_1+0.17i_2+0.16i_3+0.35j$	IV

The data in Table 4 are taken into partial connection number [19] and subtraction set pairing potential Formula (8) to get the evaluation status as shown in Table 6 and Figure 1.

Table 6 Evaluation results of water environment carrying capacity in HJ City from 2015 to 2021

Time	Grade	Positive connection number	Reverse connection number	Partial connection number	Subtraction set pair potential	Trend
2015	Ⅳ	0.77	0.69j	0.08	-0.44	partial inverse potential
2016	Ⅳ	0.65	0.63j	0.02	-0.34	partial inverse potential
2017	Ⅳ	0.53	0.54j	-0.01	-0.34	partial inverse potential
2018	Ⅲ	0.81	0.81j	0.00	-0.43	partial inverse potential
2019	Ⅲ	0.70	0.84j	-0.14	-0.39	partial inverse potential
2020	Ⅲ	0.73	0.90j	-0.17	-0.25	partial inverse potential
2021	Ⅳ	0.61	0.60j	0.01	-0.19	equilibrium potential

Fig. 1 Development trend of water environment carrying state in HJ City



According to the analysis of Table 6 and Figure 1, the partial connection number of HJ City from 2015 to 2016 is in the same trend and positive development, and the pairing potential of subtraction sets rises from -0.44 to -0.34. The trend of development of water environment carrying status shows an upward trend. From 2016 to 2018, partial connection number and subtraction set are relatively stable, and the development of water environment carrying state is relatively stable. From 2018 to 2020, the calculation results of partial connection number are less than 0, indicating that the carrying state of water environment has a downward trend, but the pairing potential of subtraction sets has increased from -0.43 to -0.25, indicating that the carrying state of water environment has an upward trend. Based on the analysis of actual data and total connection number table of HJ from 2018 to 2020, the water environment of HJ from 2018 to 2020 has improved year by year and should show a positive trend. Therefore, the partial connection number has a deviation from the analysis results of 2018 to 2020.

The main reason is that the average annual waste water discharge, COD discharge load and pesticide use load index in water environment index C of HJ city are in the minimum evaluation standard all the year round. The negative development trend of indexes A4 and C3 from 2018 to 2020 has obvious influence on the analysis of water environment carrying capacity of HJ city. Therefore, when using partial connection number analysis, the influence of water environment index on the whole water environment state is taken into excessive consideration. According to the analysis of water resources and water ecological index, the water environment state of HJ city is on the rise. From 2020 to 2021, the total partial connection number and subtraction set pairing both show a positive upward trend, and the carrying state of water environment shows a positive trend. For the analysis of development status of water environment bearing capacity in HJ city, the result of subtraction set pairing potential analysis is more objective and accurate.

It can be seen from the analysis that the carrying state of water environment in HJ city is generally showing a positive development trend, from the negative trend in 2015-2020 to the average trend in 2021. The evaluation grade has also been improved from level IV in 2015-2017 to level III in 2018-2020. The biggest influencing factor for negative development of water environment bearing capacity of HJ city is index C1, C2 and C4 in water environment index C. Among them, the per capita waste water discharge C1 increased year by year. On the one hand, it indicated that the urbanization process, industrial development and people's material life in the area were speeding up. On the other hand, it warns that the area should focus on wastewater treatment. The analysis of C4 pesticide use shows that although it is above grade 5 every year, it is decreasing year by year, showing a good development trend. C2 (COD discharge load) tends to be stable. The water resource index and water ecological index in this area have a good development trend, except the utilization rate of A4 water resources. Analyzing the utilization rate of water resources in this area, the average effective irrigation efficiency in agriculture is low, and the farmers are still used to the irrigation mode of "transporting water through soil canals and flooding with water". The reuse rate of industrial water is low, and some enterprises lack scientific water concept. Extensive waste of water in life is a serious problem.

Suggestions are put forward for HJ city as follows: (1) Vigorously promote the construction of urban sewage treatment plant, improve the scale of sewage treatment plant and centralized treatment rate of sewage, speed up the construction of regenerative water treatment plant and improve the reuse rate of reclaimed water. (2) Set up the development concept of green agriculture, continuously promote the reduction and increase of pesticides and fertilizers, popularize new water-saving irrigation technology and develop water-saving agriculture. (3) Accelerate the green development of industry, improve the awareness of energy saving and water saving, and increase the industrial water reuse rate. (4) Do a good job of urban greening to improve the urban ecological environment.

4. Conclusions

Taking HJ city as an example, this study evaluates and analyses the water environment carrying capacity of HJ city from 2015 to 2021 by using partial connection number and subtraction set pair potential evaluation method based on set pair analysis, and draws the following conclusions:

1) Aiming at the ambiguous uncertainty between sample value of evaluation index and grade of evaluation standard for water environment carrying capacity, an evaluation model of water environment carrying capacity based on five-element connection number of minimum confidence is established. The development trend of water environment carrying capacity is analyzed by using partial connection number method and subtraction set pairing method, and the method of partial connection number and subtraction set pairing is compared. It is found that the subtraction set pair potential method is closer to the reality in evaluating the bearing state of water environment.

2) The case study and evaluation of HJ city shows that the overall water environment carrying status of HJ city shows a good development trend from 2015 to 2018. The assessment level is IV from 2015 to 2017, III from 2018 to 2020 and IV from 2021. The trend of bearing state development is from negative trend to even trend, of which the best trend is in 2020.

3) Analyzing and proposing the existing water environment carrying state in HJ city, pointing out that the biggest influencing factors in this area are annual average waste water discharge, COD discharge load and pesticide use load, and proposing that industry and agriculture in this area promote green development and improve water environment carrying state.

References

1. Wang Fuqiang, Li Xin, Zhao Heng, Yang Dongming. Assessment of regional water environment carrying capacity based on water environment capacity and comprehensive index system [J]. Journal of North China University of Water Resources and Hydropower (Natural Science Edition), 2021,42 (02): 24-31
2. Song W, Pang Y. Research on narrow and generalized water environment carrying capacity, economic benefit of Lake Okeechobee, USA[J]. Ecological Engineering, 2021, 173: 106420.
3. Wang Nianqin, Pu Kaichao, Li Renwei. Comprehensive evaluation of geological environment bearing capacity of Lintong District based on variation coefficient method [J]. Groundwater, 2018, 40 (02): 77-80.
4. Li Jiao, Yan Dingrong. Research on Water Environment Bearing Capacity of Key Cities in Hunan Province and Dongting Lake District [J]. Economic Geography, 2013, 33 (10): 157-162
5. Jiang Xiaohui, Huang Qiang, Huiyanghe, et al. Study on Water Environment Bearing Capacity in Guanzhong Region of Shaanxi Province [J] Journal of Environmental Science, 2001,21 (3): 6.
6. Zhao Chuanqi, Zhu Yue, Wang Liusuo, et al. Evaluation of water environment carrying capacity of Liangzi river basin based on system dynamics and vector modulus method [J]. Science of Environmental Protection, 2021,47 (01): 136-142.
7. Zheng Zhihong, Yu Yanxu. Application of a dynamic comprehensive evaluation method in the assessment of water environment carrying capacity [J]. Water Resources and Hydropower Technology, 2016,47 (10): 54-57
8. Cheng Yang, Yao Jian. Evaluation of Water Environment Carrying Capacity in Sichuan Province Based on Improved Set Pair Analysis Model [J]. Renmin Changjiang River, 2021,52 (05): 24-29
9. Chen Wenting, Xia Qing, Su Jing, Zheng Mingxia, Xi Beidou, Xiang Wei. Early warning of water environment carrying capacity assessment of Baiyangdian watershed based on time difference correlation analysis and fuzzy neural network [J]. Environmental Engineering, 2022,40 (06): 261-271
10. Wang Bin, Wang Xi. Comprehensive assessment of resource and environment carrying capacity in karst areas -- taking Guizhou as an example [J]. Journal of Hunan University of Science and Technology (Natural Science Edition), 2022,37 (01): 118-124
11. Liu Zhiming, Zhou Zhaohong, Wang Yongqiang, et al. Study on Comprehensive Evaluation of Regional Water Resources Carrying Capacity and Sustainable Development [J]. Renmin Changjiang River, 2019, 50 (03): 145-150
12. Su Meirong, Yang Zhifeng, Chen Bin. Set pair analysis of urban ecosystem health based on emergy vitality index [J]. China Environmental Science, 2009, 29 (08): 892-896
13. Wang Wensheng, Jin Juliang, Ding Jing, et al. A new method for systematic evaluation of water resources -- set pair evaluation method [J]. Chinese Science (Part E: Technical Science), 2009, 39 (09): 1529-1534
14. Yuan, S. man ., & Li, F. xiu . Recognition criteria and application of lake eutrophication evaluation based on set pair analysis. International Journal of Scientific Research and Management, 2020,8(8), 405–413.
15. Deng Xue, Li Jiaming, Zeng Haojian, et al. Analysis of weight calculation method of analytic hierarchy process and its application [J] Practice and Understanding of Mathematics, 2012,24 (7): 8
16. Liu Qianqian, Chen Yan. Assessment of vulnerability of watershed water resources based on entropy weight method -- taking the Huaihe River basin as an example [J]. Journal of the Yangtze River Academy of Sciences, 2016,33 (09): 10-17

17. Cheng Qiansheng. Attribute recognition theoretical model and its application [J]. Journal of Peking University: Natural Science Edition, 1997 (01): 14-22
18. Zhao Keqin. Partial connection coefficient [C] Proceedings of the 11th National Academic Annual Meeting of the Chinese Association of Artificial Intelligence (II). 2005:884-886
19. Yang Hongmei, Zhao Keqin. Calculation and application of partial connection coefficient Journal of Intelligent Systems, 2019, 14 (5): 865-876
20. Hu Qiling, Dong Zengchuan, Yang Yanfei, et al. Water resources carrying capacity state evaluation model based on contact number [J]. Journal of Hohai University (Natural Science Edition), 2019, 47 (05): 425-432
21. Jin Juliang, Chen Pengfei, Zhang Haoyu, et al. Five Yuan Subtraction Set Pair Potential and Its Application in the Trend Analysis of Water Resources Carrying Capacity [J]. Journal of North China University of Water Resources and Hydropower (Natural Science Edition), 2020, 41 (02): 30-35+42