The calculation of the river water environmental carrying capacity based on the blind number

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Abstract: The water environmental carrying capacity is a basic task for water enviromental management. Based on the characteristics of uncertainty of water environmental system and the lack of water environmental information, the parameters of river water environmental system are defined as blind numbers . A fuzzy model is established through fuzzifying the parameters to calculate the river water environmental carrying capacity. The blind values of river water environmental carrying capacity are derived by using the model proposed. Study results show that the new model based on the blind number is more scientific and reasonable .

1. Introduction

At present, there are many studies on water environmental capacity. The deterministic model is simple and easy to operate, so it can be widely used.But it does not pay enough attention to the dynamic and uncertainty of the water environment system, so it is difficult to scientifically and accurately reflect the level of the real capacity of the river water. The calculation of river water environmental capacity from the perspective of uncertainty has become the trend of water pollution capacity research[1-3]. The river water environment system is a large system with fuzzy and inaccurate characteristics, so the fuzzy set theory can be used to study the river water environment problem[4,5]. In recent years, some people have tried to use fuzzy technology to simulate and characterize the randomness, fuzziness and inaccuracy of the system or things[5-7]. The blind number theory is used in the study of river water environmental capacity. On the basis of defining the number of blind parameters of water environment system, a blind number model of river water environmental capacity calculation is set up to study the water capacity of water[8-10].

2. Blind number operation[8]

2.1 Blind number

Set up $a_i \in g(I)$, $\alpha_i \in [0,1]$, i=1,2,...,n, $f(x)$ is a grey function defined on $g(I)$, and

$$f(x) = \begin{cases} \alpha_i, x = a_i \, (i = 1,2,\cdots,n) \\ 0, \qquad others \end{cases} \tag{1}$$

If $i{\neq}j$, $a_i{\neq}a_j$ and $\sum_{i=1}^{n}\alpha_i = \alpha \leq 1$, then the function $f(x)$ is a blind number. α_i is the credibility of $f(x)$ and α is the total credibility of $f(x)$.

2.2 The arithmetic of blind numbers

We can suppose that the number of blind numbers *A* and *B* is the following formula:

$$A = f(x) = \begin{cases} \alpha_i, x = x_i \, (i = 1,2,\cdots,m) \\ 0, \qquad others \end{cases} \tag{2}$$

$$B = f(y) = \begin{cases} \beta_i, y = y_i \, (i = 1,2,\cdots,n) \\ 0, \qquad others \end{cases} \tag{3}$$

The operation of blind numbers consists of two parts, one is the operation of probable values, the other is the operation of credibility.

(1)   Table 1 is called the potential band edge matrix of A and B, x_1，x_2, …x_n and y_1，y_2，… y_n are the sequence of possible values of A and B respectively. The two lines perpendicular to each other are called the longitudinal axis and the transverse axis. The * in the table can represent a +, -, x, or an operator.

(2)   Table 2 is called the confidence band edge product matrix of A about B, α_1，α_2，…α_n and β_1，β_2，…β_n are the reliability sequences of A and B. Two lines perpendicular to each other are called the longitudinal axis and the transverse axis. The first quadrant elements constitute the m * n matrix, which is called the credibility product matrix of A and B.

Table 1   the potential band edge matrix

x_1	x_1*y_1	…	x_1*y_i	…	x_1*y_n
…	…	…	…	…	…
x_i	x_i*y_1	…	x_i*y_i	…	x_i*y_n
…	…	…	…	…	…
x_m	x_m*y_1	…	x_m*y_i	…	x_m*y_n
*	y_1	…	y_i	…	y_n

Table 2   the confidence band edge product matrix

α_1	$\alpha_1\cdot\beta_1$	…	$\alpha_1\cdot\beta_j$	…	$\alpha_1\cdot\beta_n$
…	…	…	…	…	…
α_i	$\alpha_i\cdot\beta_1$	…	$\alpha_i\cdot\beta_j$	…	$\alpha_i\cdot\beta_n$
…	…	…	…	…	…
α_m	$\alpha_m\cdot\beta_1$	…	$\alpha_m\cdot\beta_j$	…	$\alpha_m\cdot\beta_n$
·	β_1	…	β_j	…	β_n

3. Blind number model of river water environmental capacity calculation

The formula for calculating the water capacity of fully mixed water under steady state conditions is expressed as follows:

$$W = Q(c_s - c) + kc_s V = Q(c_s - c) + kc_s Qx / u \tag{4}$$

In the formula, *Q*—river flow；*u*—velocity；*x*—river length；*cs*—water quality target；*c*—pollutant concentration；*k*—pollutant degradation coefficient.

It is obvious that the formula reflects the amount of pollutants that the river can bear in a given case, but because of the instability of the river, the changes in the flow and flow rate of the river cannot represent the water environmental capacity of the river, so it cannot reflect the actual water level of the water.

The river flow *Q,* pollutant concentration *C* and flow velocity *u* are respectively constructed as blind numbers. It can characterize the randomness and fuzziness of the system or things. They are

$\{[Q_{i1},Q_{ip}],f_i(Q)\}$、 $\{[c_{i1},c_{ip}],f_i(c)\}$ and $\{[u_{i1},u_{ip}],f_i(u)\}$. A blind number model for calculating water environmental capacity can be obtained by substituting the above blind number into formula (4).

$$W= \{[Q_{i1},Q_{ip}],f_i(Q)\}(c_s - \{[c_{i1},c_{ip}],f_i(c)\})$$
$$+kc_s\{[Q_{i1},Q_{ip}],f_i(Q)\}x/\{[u_{i1},u_{ip}],f_i(u)\} \qquad (5)$$

4. Calculation example

The Huaihe River Basin has a long tributary of about 12km. According to the measured data of the annual flow, flow rate and COD_{Mn} concentration in 2007, the pollutant degradation coefficient of the river section is k=1.16×10-6 /s, and the water quality control target of the river section is cs=15mg/L. The following formula can be obtained by constructing blind parameters.

$$W = 86400 \times 10^{-3} \times f(Q)(15 - f(c)) + 86400 \times 10^{-9} \times 1.16 \times 15 \times 12000 \times f(Q)/f(u)$$
$$= 86.4 \times [f(Q)(15 - f(c)) + 0.21 \times f(Q)/f(u)] \qquad (6)$$

The possible value of water environmental capacity and its corresponding credibility can be obtained by using the algorithm of blind number. The interval of possible values can be converted to intersected interval values, and a 9 order blind number of the difference between the upper and lower limits of each interval is finally obtained. We can see the Table 3 below.

Table 3   The possible value interval and its reliability of the 9 order blind number

possible value	reliability	possible value	reliability
[600,1600]	0.15	[5600,6600]	0.06
[1600,2600]	0.26	[6600,7600]	0.01
[2600,3600]	0.24	[7600,8600]	0.01
[3600,4600]	0.19	Others	0
[4600,5600]	0.08		

After transformation, the possible range of water environmental capacity and its corresponding reliability can be obtained, as shown in Table 4 below.

Table 4   The range and reliability of the possible value of water environmental capacity

possible value (kg/d)	reliability	possible value(kg/d)	reliability
[43300,129700]	0.15	[475300,561700]	0.06
[129700,216100]	0.26	[561700,648100]	0.01
[216100,302500]	0.24	[648100,734500]	0.01
[302500,388900]	0.19	Others	0
[388900,475300]	0.08		

5. Conclusion

In the calculation of water environmental capacity, the deterministic steady-state model is usually used to calculate the water environmental capacity. Although the calculation process of the deterministic model is relatively simple, it ignores the fuzziness, randomness, fuzziness and unascertained of the river water environment system.

The calculation model of river water environment capacity under blind information is established by blind number theory from the angle of various uncertainties of water environment system. According to the model, it can not only obtain the possible range of possible value of the river water environment capacity, but also obtain the corresponding confidence values in each interval. Therefore, it is more scientific and reasonable than the deterministic method.

It is of practical significance to study river water environmental capacity by using blind number theory. This method is applicable not only to the study of river environmental capacity, but also to the

calculation of water environmental capacity of other water bodies, such as lakes and reservoirs.

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