Evaluation of the water quality of the Yangtze River Based on the comprehensive pollution index model

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Abstract

In view of the present situation of water pollution in the Yangtze River Basin, the comprehensive pollution index method is used to judge whether the water quality standard or exceed the standard. We use the size of P to evaluate the water quality of the Yangtze River comprehensively. And use the standard deviation of the proportion of each individual to seek the weight of pollution indicators, and finally analyze the water pollution situation of 17 stations. In this paper, we judge the amount of sewage by using discharge rate. By seeking the upper and lower bounds of the amount of sewage in each section of the Yangtze River, we get the section of the Yangtze River sewage ranking in the largest amount. This solution solves the trouble caused by unknown quantity (the number and the corresponding amount of sewage in a river outfall).

Keywords

Integrated pollution index model, Discharge rate, Water quality category, Gray prediction.

1. Water Quality Assessment Model

Based on the comprehensive evaluation of the water quality data of 17 stations in the past year,combined with four indicators of water pollution,and the pollution index method was used to compare the measured value with the national standard,so as to evaluate the water quality.According to the statistical properties of the observed value, the weight is calculated and the comprehensive pollution index is obtained.According to the comprehensive pollution index,we determine whether the comprehensive water quality standard, and then analyze the water pollution situation in each region.

1.1 Pollution Index Model

Pollution index method is based on the evaluation method of water environment function area[3] .

Establish the single pollution index In view of the single water quality index

In view of the single water quality index ,that is:ammonia nitrogen(NH3-N), Dissolved oxygen (DO),Permanganate index (CODMn) and pH value.Compared the measured values with the corresponding water quality standards of the water environment functional area ,we get the single pollution index,that is:

$$I_i = \frac{C_i}{S_i}, i = 1,2,3,4, \tag{1}$$

In (1), C_i is the measure the water quality indicators, S_i is the concentration limit of the single water quality index corresponding to the functional category of water quality. I_i is the single pollution index of the I indicators.

Weighted Average Composite Index

The individual water quality indexes of the comprehensive water quality assessment, stage:< surface water environment quality standard >(GB3838 - 2002)the 4 main monitoring projects，The selected the single pollution index of the four main indexes by arithmetic mean, weighted average, multiplication and index and other mathematical methods to get a comprehensive index [4]，And then to evaluate the comprehensive water quality.

Weighted average comprehensive exponential formula is:

$$P = \sum_{i=1}^{n} w_i I_i = \sum_{i=1}^{n} w_i (\frac{C_i}{S_i}),\ i = 1,2,3,4, \tag{2}$$

P stands for the comprehensive pollution index, n is the single index of water quality in comprehensive water quality assessment . w_i is the indicators of the weight of i, I_i stands for the single index pollution index of i .

1.2 Determination of weight of pollution index formula

According to the individual water quality index, we can get

$$w_i = \frac{\sigma_i}{\sum_{i=1}^{n} \sigma_i},\ i = 1,2,3,4, \tag{3}$$

σ_i reflects the magnitude of the deviation of each factor concentration. By the formula (3) we can see the greater σ_i is, the greater the single quality index is . The data in the water quality testing report of the main cities of the Yangtze River Basin, the annex 3,the value of the four main testing items from June 2004 to September 2005 were summarized respectively and descriptive statistical analysis was performed. Using statistical software to get the corresponding analysis data of the other 16 observation stations, the comprehensive evaluation of the Yangtze River was carried out by the standard deviation of the four main indexes of the 17 observation stations, The value of the w_i is the weight of each water quality index. That is:

$$P = \sum_{i=1}^{4} w_i I_i = 0.1571 I_1 + 0.4973 I_2 + 0.3416 I_3 + 0.0940 I_4 \tag{4}$$

1.3 determination of the single pollution index

From table 4 we can see that the four main testing items are the standard limits, and water quality testing report of the main cities of the Yangtze River Basin from June 2004 to September 2005 based on the annex 3:17 observation station, and monthly water quality categories for each observation station, we can know S_i .

The measured value of the water quality index C_i has been given In the water quality monitoring report. Therefore we can get I_i by using formula 1.

First take Panzhihua, Sichuan, for example, the calculation results are shown in table 1.

Comprehensive pollution index is to determine the degree of comprehensive water quality standards for water environment function area,P is less than or equal to 1,it means water quality standards, otherwise the comprehensive water exceeded.From table 1 we can see the comprehensive pollution index of Panzhihua Sichuan P=1.0314>1, that is, the comprehensive water quality in Panzhihua, Sichuan exceed the standard .

Table 1: single water pollution index and comprehensive pollution index in Panzhihua, Sichuan

Time	$I_1(NH_3\text{-}N)$	$I_2(DO)$	$I_3(CODMn)$	P(integrated pollution index)
July 2004	0.080	1.410	0.600	0.9187
August 2004	1.000	2.780	0.970	1.8709
September 2004	0.060	0.942	0.610	0.6863
October 2004	0.533	1.296	0.400	0.8649
December 2004	0.533	1.373	0.800	1.0398
January 2005	0.467	1.360	0.600	0.9547
February 2005	1.000	1.251	0.450	0.9329
March 2005	0.520	1.600	0.275	0.9713
April 2005	0.667	1.204	0.550	0.8914
May 2005	0.140	1.397	0.625	0.9302
June 2005	0.160	1.467	0.725	1.0023
July 2005	0.160	1.437	1.000	1.0814
August 2005	0.180	1.488	0.625	0.9818
September 2005	0.160	1.417	1.000	1.0714
P(integrated pollution index)				1.0314

Using the same method,the comprehensive pollution index of 17 stations can be obtained in turn.And sort it out,, the result is as shown in table 2.

Table 2: ranking of the total water quality and main pollutants for each observation station of the Yangtze River

Serial number	Observation station name	P comprehensive pollution index	Total water quality ranking	Major pollutants
1	Sichuan Panzhihua Longdong	1.0314	7	ammonia nitrogen,Permanganate index
2	Chongqing Zhutuo	1.0002	5	-
3	Hubei Yichang nanjinguan	1.2704	13	-
4	Yueyang Chenglingji Hunan	1.1420	10	-
5	Jiujiang water plant in Jiangxi	0.9847	4	-
6	Anqing Estuary in Anhui	1.0501	8	-
7	Mount Nanjing, Jiangsu	0.8594	1	-
8	Sichuan Leshan Minjiang Bridge	1.2940	14	dissolved oxygen ,ammonia nitrogen ,permanganate index
9	Yibin Sichuan cool ginger ditch	1.5081	16	permanganate index ,ammonia nitrogen
10	Sichuan Luzhou River Bridge	1.4001	15	dissolved oxygen ,ammonia nitrogen ,permanganate index
11	Hubei Danjiangkou	0.9105	3	-

	Hu Ling			
12	Changsha Xingang Hunan	1.0145	6	dissolved oxygen ,ammonia nitrogen
13	Yueyang Tower in Yueyang, Hunan	1.7501	17	permanganate index
14	Wuhan, Hubei customs clearance	0.8664	2	-
15	Jiangxi Nanchang Chu cha	1.1905	11	permanganate index,ammonia nitrogen
16	Jiujiang Jiangxi toad stone	1.1100	9	permanganate index
17	Yangzhou Sanjiang Jiangsu camp	1.2009	12	permanganate index

As can be seen from the table 6, the situation of water pollution of each observation station of the Yangtze River, the comprehensive pollution index of Yueyang Tower in Yueyang, Hunan is the highest.The main pollutants are permanganate index and the worst is its water pollution.Followed by Yibin Sichuan cool Jiang ditch,the third serious water pollution is Sichuan Luzhou Tuojiang bridge;The best area of water quality is in Nanjing, Jiangsu Lin Shan.The comprehensive pollution index of Wuhan, Hubei, is also low, whose water quality is second only to Nanjing, Jiangsu.

2. To Determine The Model Of The Main Pollution Of The Yangtze River

2.1 The Establishment Of the Model

Suppose the distribution of concentration of pollutants in the Yangtze River is $C(mg/L)$, Mean velocity is $v(m/s)$,distance is $x(km)$,C satisfy one dimensional water quality model: $v\frac{dC}{dx}+kC=0,$ The K is for pollutants degradation coefficient (K=0.2).If Initial value condition is $C(0)=C_0$, then the natural degradation law of the concentration of pollutants with the flow of water is $C=C_0e^{-k\frac{x}{v}}$.

For a section of the Yangtze River AB, that is A is the beginning, B is the end, then the distance is d（m）.we can suppose this section has n outfalls, the flow rate, average flow rate, concentration of pollutants in the I sewage outfall is q_i,v_i,c_i .While Q_i,V_I,C_i stands for the river water respectively flow, velocity and contaminant concentration, then:

$$C_i=\frac{q_ic_i+Q_{i-1}f(C_{i-1})}{Q_{i-2}q_i},Q_i=Q_{i-1}+q_i(i=1,2,3,...,n+1), \quad (1)$$

And $f(C_{i-1})=C_{i-1}e^{-k\frac{x_{i-1}}{V_{i-1}}}$, If we have known the water flow rate, flow rate, pollutant concentration of the starting point A and end point B is q_0,v_0,c_0 and q_{n+1},v_{n+1},c_{n+1} , Then the total amount of sewage in the river for AB is $w_{AB}=\sum_{i=1}^{n}c_iq_i$.

Next, calculate the maximum total amount of pollution (upper bound) and the minimum discharge (lower bound).

(1) The upper bound of pollutant discharge

Suppose all of the sewage assumptions are concentrated in the point A (the source).and it get to B after a period of degradation of AB. And $C_B = C_1 e^{-k\frac{x}{v_B}}$, then, $C_1 = C_B e^{k\frac{x}{v_B}}$.According to formula(1) , we can get $C_1 = \frac{q_1 c_1 + Q_0 C_0}{Q_0 + q_1} = \frac{q_1 c_1 + Q_A C_A}{Q_B}$ .Therefore, the upper bound of the total amount of pollution in the section within the value is;

$$w_{\max} = q_1 c_1 = C_1 Q_B - Q_A C_A = Q_B C_B e^{k\frac{x}{v_B}} - Q_A C_A (g/s) \quad (2)$$

(2) The lower bound of the pollutant discharge

Suppose all of the sewage assumptions are concentrated in thepoint B (the ending).as the method of getting the upper bound value, we can get the lower bound value, that is $w_{\min} = q_1 c_1 = Q_B C_B - Q_A C_A e^{-k\frac{x}{v_B}} (g/s)$.

(3) Average relative emission

Average relative pollutant discharge is a comparable index. The index size can be determined to get the largest displacement section of Yangtze River. It can be regarded as the main source of pollution. Every month, each section can determine the change interval for a blow down amount, The change of interval emissions for the j month is $\left[w_{\min}^{(j)}, w_{\max}^{(j)}\right](j = 1, 2, ..., 13)$ .Then take the average, $\overline{w}_{\min} = \frac{1}{13}\sum_{j=1}^{13} w_{\min}^{(j)}, \overline{w}_{\max} = \frac{1}{13}\sum_{j=1}^{13} w_{\max}^{(j)}$ So you can determine the amount of sewage is a section of each interval $\left[\overline{W}_{\min}, \overline{W}_{\max}\right]$. Then take median, $W_{med} = \frac{1}{2}\left(\overline{W}_{\min} + \overline{W}_{\max}\right)$, that Is the average amount of sewage of 13 months of a section. If the length of the distance is $d(km)$, Each section of the second, emissions per kilometer is: $w_0 = \frac{w_{med}}{2} (kg/s \cdot km)$.That is, the average relative amount of sewage.

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2.2 Slving Model.

According to statistics of the Yangtze River seven related data, According to the steps of the above model, the solution is carried out for CODMn and NH3-N, Sichuan Panzhihua, Hubei Yichang, Chongqing Zhu Tuo, Hunan Yueyang, Jiangxi Jiujiang, Anhui Anqing are respectively remembered as $S_1, S_2, S_3, S_4, S_5, S_6, S_7$. Then the following table results are available, as shown in Table 3 and Table 4.

Table 3: emission and ranking results

section	S1-S2	S2-S3	S3-S4	S4-S5	S5-S6	S6-S7
[min,max]	[31.32,49.03]	[30.07,68.07]	[39.12,78.72]	[20.29,49.04]	[14.15,18.58]	[23.16,40.15]
Relative emission	0.048	0.048	0.15	0.0693	0.0998	0.0682
sort	6	5	1	3	2	4

Table 4: emission and ranking results

section	S1-S2	S2-S3	S3-S4	S4-S5	S5-S6	S6-S7
[min,max]	[28.11,63.12]	[30.47,83.58]	[42.52,113.09]	[22.52,60.78]	[15.79,22.05]	[8.47,28.1]
Relative emission	0.048	0.0733	0.197	0.0833	0.1154	0.0393
sort	5	4	1	3	2	6

Conclusion can be drawn as follows:

The pollution source of the Yangtze River more than a year of major pollutants permanganate index mainly in Yichang and Hunan Yueyang Hubei, At the same time, the pollutants ammonia nitrogen pollution source of the Yangtze River of nearly a year is mainly in Yichang, Hubei and Hunan Yueyang.

3. Result Analysis

The comprehensive evaluation of the water quality of the Yangtze River, as well as the analysis of the pollution situation of each observation site,In this paper, we use the comprehensive pollution index method.The ratio of the measured value of the four main testing items to the standard limit is used as the pollution number of the single index.And obtains the weight, thus obtains the comprehensive pollution index formula,And analyze the water pollution situation of each observation site. To determine the main pollution source of the Yangtze River model,The discharge amount of each section of the Yangtze River was analyzed and calculated,By seeking the upper and lower bounds of the amount of sewage in each section of the Yangtze River, a comparability index is obtained,that is average relative discharge.we get the largest section of Yangtze River sewage by sorting.This just solve trouble caused by the unknown quantity (number and corresponding emissions of a river outfall) .

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