Research on Dynamic Characteristics of River Pollution Degradation Coefficient in the Main Stream of Weihe River

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Abstract. In order to reveal the influence of different hydrological conditions and dynamic changes of pollution sources on the degradation coefficient of pollutants, this study took the main stream section of the Weihe River as the research object to analyze and study the dynamic characteristics of the degradation coefficient of pollutants in the river. Taking the dry year as the representative hydrological year, according to the measured data of each section of the Weihe River, the parameter estimation method based on Matlab regression analysis was used to calculate the comprehensive degradation coefficients of CODcr and NH3-N under different hydrological conditions in each section. The simulation verifies and verifies the calculation results. The results show that different comprehensive degradation coefficients of pollutants under different hydrological conditions are more in line with the actual situation of river pollutant degradation.

1. Introduction

The comprehensive degradation coefficient of pollutants reflects the speed and slowness of the degradation of pollutants in water, and is one of the most critical parameters in the calculation of pollutant absorption capacity. Whether its value is reasonable or not directly affects the calculation result of pollutant absorption capacity and the implementation of the total amount control scheme [1]. Wu Jihong [2] used the measured data to calculate the pollutant degradation coefficient of the Yellow River trunk stream. Tao Wei and Liu Ying et al. [3] measured the degradation coefficient of ammonia nitrogen in Yibin section of the Yangtze River by means of laboratory simulation. Li Jinxiu and Liao Wengen [4] deeply studied the influence of the huge changes in the flow conditions before and after the completion of the Three Gorges Reservoir on the biochemical degradation coefficient of BOD₅, and established empirical relations related to the flow conditions. These methods are basically researching on the comprehensive degradation coefficients of pollutants under the same hydrological conditions, the same river reach and channel conditions, but because the hydrological process of the river has obvious dynamic characteristics, and the pollution source also has a time variation law, the
hydrological elements and pollution sources directly affects the change of the comprehensive degradation coefficient of pollutants. Therefore, it is necessary to carry out research on the comprehensive degradation coefficient of pollutants under different hydrological conditions in different periods of river reach, improve the calculation accuracy of river pollution, and provide more effective support for river water pollution control and water environment management.

In recent years, although the water pollution of the Weihe River has improved, CODcr and NH$_3$-N are still the main pollutants in the river waters of the mainstream and tributaries of the Weihe River [5]. This study uses a large amount of measured data to calculate the CODcr and NH$_3$-N degradation coefficients under different hydrological conditions and different sections of the Weihe River. It provides an important basis for establishing river water quality models, calculating pollution capacity, and protecting the centralized drinking water source of the Weihe River data and scientific evidence.

2. Calculation method and parameter setting

2.1. Calculation method

The biodegradation, sedimentation and other physicochemical processes of pollutants can be summarized as the comprehensive degradation coefficient of pollutants in the process of determining the carrying capacity of water. The main influencing factors are [6-7]: initial concentration, pollutant concentration gradient, pollutant properties and combined effects, water temperature, hydrological characteristics (including flow, flow velocity, water depth, river width, sediment concentration, etc.) and channel conditions. The two-point method is adopted to calculate the degradation coefficient of pollutants, which can be divided into the following three steps: (1) Select river reaches and analyze water quality monitoring data of upper and lower sections; (2) Analyze and determine the average velocity of the reach, and use the model to calculate the comprehensive degradation coefficient of pollutants; (3) Verify the calculation results and determine the comprehensive degradation coefficient of pollutants.

Calculation formula of one-dimensional water quality model:

\[
c = c_0 \exp \left( -k \frac{x}{86.4u} \right)
\]

(1)

Where, \( c_0 \) is the concentration of pollutants at the initial section, mg/L; \( c \) is the monitoring value of pollutant concentration in the lower section, mg/L; \( x \) is the length of river reach, km; \( u \) is the average velocity of the reach, m/s; \( k \) is the comprehensive degradation coefficient of pollutants, d$^{-1}$.

\[
c_0 = (c_R Q_R + c_E Q_E) (Q_R + Q_E)^{-1}
\]

(2)

Where, \( Q_R \) is the upstream incoming water flow, m$^3$/s; \( c_R \) is the concentration of upstream water quality, mg/L; \( Q_E \) is sewage flow m$^3$/s, \( c_E \) is sewage discharge concentration, mg/L.

Since the selected reach is certain, the logarithm of both sides of formula (1) is taken to obtain:

\[
\ln c = \ln c_0 - k \frac{x}{86.4u}
\]

(3)

Make
\[ Y = \ln c \quad a = \ln c_0 \quad X = \frac{x}{86.4u} \quad b = -k \quad (4) \]

Then formula (3) becomes

\[ Y = a + bX \quad (5) \]

Under the condition that a series of pollutant concentration data \((u_i, c_i)\) \((i=1,2,...,n)\) of the river reach are known, it can be converted into \(n\) groups \((X_i, Y_i)\) \((i=1,2,...,n)\) through equation (4). Then, regression analysis is conducted on equation (5) based on Matlab to obtain the optimal estimated values of parameters \(a\) and \(b\). According to equation (6), the comprehensive degradation coefficient \(k\) of pollutants can be obtained:

\[ k = -b \quad (6) \]

2.2. Parameter condition analysis

Because different river sections have different flows in different water periods (abundant, flat, and dry periods), corresponding to the comprehensive degradation coefficient of water quality at different flow rates. In this study, the pollutant degradation coefficient was calculated month by month for the selected typical years, and then the mean value of different periods was taken as the pollutant degradation coefficient of river reach in that period. Finally, the water quality monitoring data of adjacent periods were used to verify the calculated results to determine the comprehensive degradation coefficient of pollutants.

According to the statistical analysis of the water quality and hydrological monitoring data collected from the hydrological yearbook of the People's Republic of China and other relevant documents in the past 10 years, the water inflow in the Weihe River basin from July to October 2006 (wet season) was relatively low compared with the average value of the previous years. It can be seen from the analysis that 2006 is a dry year, and its wet period has a high guarantee rate in the corresponding hydrological series. Therefore, no matter the annual type or the annual distribution, this year is suitable for the design hydrological year to calculate the comprehensive degradation coefficient of pollutants.

3. Inversion of pollutant degradation coefficient

The degradation coefficients of COD and NH\(_3\)-N were calculated by using the monitoring data of the main stream of Weihe River. The degradation coefficients of COD and NH\(_3\)-N are calculated using water quality monitoring data from 2004 to 2006, and the pollutant degradation coefficients are calculated month by month under the hydrological conditions in the dry year of 2006, and then the average value is taken as the pollutants of the river section in this period. Degradation coefficient. Based on the parameter estimation of matlab regression analysis, the squared correlation coefficient is close to 1.0, and the P value is close to 0. The calculation results are shown in Table 1, Table 2 and Table 3.

| Table 1. The calculation results of monthly COD degradation coefficient in Shaanxi section of Weihe River. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| results | 0.246 | 0.245 | 0.260 | 0.263 | 0.261 | 0.264 | 0.287 | 0.288 | 0.288 | 0.285 | 0.247 | 0.246 |
Table 2. The calculation results of monthly Ammonia nitrogen degradation coefficient in Shaanxi section of Weihe River.

| month | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   | 11   | 12   |
|-------|------|------|------|------|------|------|------|------|------|------|------|------|
| river |      |      |      |      |      |      |      |      |      |      |      |      |
| results | 0.097 | 0.098 | 0.140 | 0.142 | 0.143 | 0.143 | 0.202 | 0.202 | 0.204 | 0.204 | 0.099 | 0.097 |

Table 3. The calculation results of different water period degradation coefficient in Shaanxi section of Weihe River.

| Water period   | Rainy season (7~10 month) | Level period (3~6 month) | Dry season (11~2 month) |
|----------------|---------------------------|--------------------------|-------------------------|
| river COD NH$_3$-N COD NH$_3$-N COD NH$_3$-N | | | |
| results       | 0.287 | 0.203 | 0.262 | 0.142 | 0.246 | 0.098 |

It can be seen from the results that the degradation coefficient of pollutants in rainy season is higher than that in level period and dry period. This is because the greater the flow rate of the river is, the more conducive to the mixed dilution of pollutants, and the self-purification degree is relatively fast. In summer (rainy season), the water temperature is high, which is conducive to the degradation of pollutants; in winter (dry season), the water temperature is low, and the biodegradation and volatilization decrease. In recent years, with the rapid development of cities within the basin, the discharge of urban sewage increases greatly, which leads to the low degradation rate of pollutants in the dry period of rivers.

4. Verification and analysis of parameter inversion results
The 2008 monitoring data were used to verify the accuracy of the degradation coefficient. The comparison between the measured value and the calculated value of Weihe River is shown in figure 1 and figure 2.

![Figure 1. COD concentration of computational results of Weihe River.](image-url)
It can be seen from the verification results in figure 1 that the reverse calculation results of COD are basically consistent with the measured values, with errors within 20% and a reliable degradation coefficient. In figure 2, the inverse calculation result of NH$_3$-N is far from the measured value, which is not as good as COD. However, the inverse calculation results of COD and NH$_3$-N are in good agreement with the measured values.

5. Conclusion
Using this method, the degradation coefficients of different pollutants in different rivers and river reaches in different water periods are obtained. The concentration values of COD$_{Cr}$ and NH$_3$-N calculated by the inverse method are in good agreement with the measured values. It shows that the degradation coefficients of COD$_{Cr}$ and NH$_3$-N obtained by this method are more reliable and more in line with the actual situation of rivers, which can provide important information for the establishment of river water quality model and the analysis and calculation of pollutant carrying capacity Technical support.

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