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Abstract: In order to solve the problems of high measurement time-consuming, high deviation and small area in traditional methods, a water resource pollution load intensity measurement based on SWAT model is proposed. Firstly, build a basic database, which contains different types of water resources data. Then, the hydrological characteristic data in the basic database are summarised, and the SWAT model is used to design the water pollution output coefficient model to obtain the change results of water pollution parameters; Finally, the comprehensive pollution index method is used to measure the pollution load intensity of water resources, obtain the standard pollution index, and get the final measurement result. The experimental results show that the water pollution load intensity measurement of this method takes less time, the measurement result deviation is low, and the area that can be measured is large, and the measurement effect is better.

Keywords: SWAT model; water resource; pollution load intensity; standard pollution index; comprehensive pollution index method; attribute data.

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1 Introduction

Water resource refer to water resource available or likely to be used in sufficient quantity and of suitable quality to meet the needs of specific use in a certain place over a period of time. Water resource also refer to water on the earth with a certain quantity and available quality that can be replenished and used from nature. In human production and life, water resource is an essential survival element. If water resource is absent or polluted seriously, it will have a serious impact on people's daily life. Therefore, people have higher and higher requirements on water quality (Zhou et al., 2021). However, due to the excessive development and utilisation of water resource, serious water resource pollution has been caused and the pollution load intensity of water resource has increased. The pollution load intensity of water resource refers to the impact of various pollution sources and pollutants on the environment obtained from the evaluation of multiple pollution sources and pollutants discharged (Diary et al., 2019). Only by clearly measuring the pollution load intensity of water resource at the present stage can we understand the current situation of water resource utilisation and pollution and provide a reliable basis for subsequent pollution prevention and treatment (Wang et al., 2020). Therefore, it is of great significance to study a measurement method of water resource pollution load intensity.

For the measurement of water pollution load intensity, many scholars have broadened their research ideas and analysed and explored related issues. Han et al. (2020) proposed a measurement method of water resource pollution load intensity based on ADE-GA, which mainly used the method of combining convection diffusion equation (CDE) and genetic algorithm (GA) to identify groundwater pollution sources, namely, the location of pollution sources, the time and intensity of pollution release. The results are taken as the measurement results of groundwater pollution load intensity and used to deal with water pollution. However, it is found in the experiment that the identification results obtained by this method are consistent with the pollution source parameters of the actual results, and it has a good pollution source identification performance, but it takes a long time to measure the pollution load intensity of water resource. Li and Cao (2020) is put forward based on the wavelet decomposition of water pollution load intensity analysis method, this method through the establishment of administrative units and rural tourist area water pollution load intensity measurement model, combined with the measurements of entropy Gini coefficient method is used to design the short-term prediction rules, implement the short-term forecasting of water pollution load, by using the prediction results for water pollution control. However, this method has the problem of high deviation of measurement results. Qiu et al. (2019) proposed a measurement method of water resource pollution load intensity based on FCM fuzzy clustering algorithm. Aiming at analysing water resource consumption intensity, this method established an evaluation system of water resource consumption intensity, which was used to select some cities for example analysis. FCM fuzzy clustering algorithm was used to divide the experimental area and measure the intensity of water resource pollution load in different areas. However, in the practical application process, it is found that this method can measure a small area, and there is a big gap with the ideal application effect.

Although these traditional methods are water pollution intensity evaluation, measurement ability, but because the actual geographical environment, partly due to the inconsistency of water quality, without proper database to store the information, causing subsequent water pollution output coefficient calculation error is bigger, this time the strength measurement of these methods is still long, In addition, there are some errors in the prediction results of Water resource pollution load intensity and the measurement range is small. In order to solve this problem, this paper proposes a Water resource pollution load intensity measurement method based on Soil and Water Assessment Tool (SWAT) model. Therefore, this method has the characteristics of lower measurement time and measurement result deviation, larger measurement area and better measurement effect. The overall scheme of the method is as follows:

Step 1 Build a basic database containing different types of water resource data, and subdivide the data types in this database into spatial data and attribute data.

Step 2 The hydrological data of hydrology, soil, climate, agricultural management, nutrients and crop yield in the basic database were summarised by using SWAT model, and the output coefficient model of water resource pollution was designed to obtain the variation of water resource pollution parameters. According to the variation of water resource pollution parameters, the comprehensive pollution index method is used to measure and analyse the water resource pollution load intensity, obtain the standard pollution index, and get the final measurement result of water resource pollution load intensity.

Step 3 Experimental tests are carried out to verify the application performance of different methods.

2 Design of water resource pollution load intensity measurement method

The SWAT model can be used to predict soil types, analyse land management conditions, determine land use forms, and simulate the quality of water resource. In the current practice of applying the model, it is mainly through collecting specific parameters such as soil topography, characteristics, vegetation or weather, and directly inputting different parameter conditions into the model, which has the characteristics of low operation complexity and clear results (Yuan and Zhang, 2021). Therefore, this paper selects the SWAT model to measure the intensity of water pollution load.

2.1 Build basic database of water resource pollution

Before using SWAT model to measure water pollution load intensity, need to build a basic database. The database contains a large number of data types, covering all the data used in water pollution load intensity analysis. The data types in the database can be divided into spatial data and attribute data. Among them, spatial data include water pollution discharge location, digital elevation model (DEM), soil type, etc. (Ren and Li, 2021). Attribute data includes meteorological data, soil attribute data, point source pollution discharge data or reservoir basic information data. Taking the attribute data of the input spatial dataset as the natural feature data, the water resource information to be studied is divided into multiple research areas (Zhang et al., 2019). The details of the SWAT model database are shown in Table 1.

Table 1 Description of data details in the SWAT model

Type of data	*Specific name*	*Details*	*Data sources*
Spatial data	Soil type	Soil type	Paper map vectorisation
	DEM	Slope, elevation, aspect	Geospatial cloud
	Land use	Land use status in the research area	TM data interpretation
Attribute data	Soil properties	Hydrological grouping, saturated hydraulic conductivity, etc.	Field sampling
	Land use type	Different attributes of land use	Amount or related order
	Meteorological data	Daily precipitation, wind speed, sunshine temperature, etc.	Provide data
	Hydrological data	Daily flow, quicksand, etc.	Model comes with

In Table 1, the land use factor in spatial data is the key factor affecting the pollution level of water resource, that is, human factors have a great impact on the water environment; meteorological data and hydrological data in attribute data are the key factors affecting the pollution level of water resource, that is, the impact of natural factors on water environment. Therefore, the next step is to measure and analyse the pollution load intensity of water resource mainly from these two factors.

2.2 Construction of water resource pollution output coefficient model based on SWAT model

Based on the above basic database of water resource pollution, the water pollution situation is analysed according to the types of water resource pollution. According to the current water pollution situation, the forms of water pollution are mainly divided into natural pollution and man-made pollution. In natural pollution, it is mainly due to the melting of part of the geology caused by rainfall. The rainfall process washes the ground, making it easy for various pollutants to wash into water resource and flow into water bodies (Meng et al., 2020). Man-made pollution accounts for a large proportion of the overall water pollution, but it can be controlled in essence. As long as a reasonable overall planning is required, the goal of water pollution control can be achieved. Among the different types of water pollution, different pollution sources can be sorted out, mainly including: organic pollution, pathogen pollution, heavy metal pollution, plant nutrient pollution, radioactive pollution, aerobic pollution, thermal pollution, salt pollution and other eight pollution sources (Hong et al., 2019). Under the condition of understanding the types of water pollution and pollution sources, quantitatively design the output of water pollution and determine the water pollution model.

SWAT model can summarise information according to the hydrological characteristic data on land. The main hydrological characteristic data include hydrology, soil, climate, agricultural management, nutrients and crop yield. The hydrological characteristics are used to describe the migration process of pollutants and understand the migration, transformation and sensitivity of water resource pollution (Tsaboula et al., 2019). Therefore, combined with the sensitivity index analysis method, the sensitivity of water pollution load is analysed to determine the value range of different water pollution output coefficients. Conduct random sampling of water resource to determine two random sequence matrices with appropriate differences, as shown in formulas (1)~(2):

$$M_1 = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

$$M_2 = \begin{bmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{m1} & \cdots & y_{mn} \end{bmatrix} \tag{2}$$

Among them, m represents the number of repeated sampling, represented by the total number of rows in the matrix; n represents the number of water pollution parameters, represented by the total number of columns in the matrix.

The two sequence matrices randomly selected above have different statistical characteristics and can be used to fully reflect the change state of water resource pollution. By combining the two, a joint matrix can be obtained to calculate the change of each water resource pollution parameter (Grbi et al., 2020):

$$M' = M_1 \times M_2 = \begin{bmatrix} S_{x1} & \cdots & S_{xn} \\ \vdots & \ddots & \vdots \\ S_{y1} & \cdots & S_{xy} \end{bmatrix} \tag{3}$$

Under the action of the above matrix, a water resource pollution output coefficient model is established:

$$Y^2 = \left(y_{max} - y_{min}\right) / \left(f_{max} - f_{min}\right) \tag{4}$$

Among them, y_{max} and y_{min} represent the maximum and minimum pollution load of regional water resource, respectively; f_{max} and f_{min} represent the maximum and minimum pollution load of overall water resource, respectively.

Because the variability of the environment will have a certain impact on the pollution coefficient of water resource, and the change of water resource pollution parameters can reflect this problem, it can be seen that the water resource pollution output coefficient model designed in this paper has the characteristics of dynamic variability.

2.3 Water resource pollution load intensity measurement is realised

According to the above water resource pollution output coefficient model, the variation results of water resource pollution parameters are obtained, and the comprehensive pollution index method is used to measure the water resource pollution load intensity to obtain the standard pollution index and obtain the final measurement results.

Generally, most scholars use the single factor evaluation method to measure and analyse the pollution load intensity of water resource, mainly by setting the standard value, then monitoring the water quality, and finally comparing the two to obtain the measurement results (Hossain and Patra, 2020). This method has the characteristics of simple operation, but because the pollution degree of different pollutants is different, it can not be generalised. This method has the problem of inaccurate measurement results, so it needs to be improved.

This paper fully considers the shortcomings of the traditional single factor evaluation method, and will use the comprehensive pollution index method to measure and analyse the water pollution load intensity. The water pollution load intensity measurement is to evaluate the water pollution state, so as to take preventive and response measures, avoid large-scale sudden water pollution events and reduce the local water pollution risk.

The assessment of pollution load intensity of water resource specifically includes the risk assessment of pollution sources and the risk assessment of environment and development after water pollution. This method first obtains the standard pollution index, which is mainly obtained by comparing the water pollution monitoring concentration with the standard (Tidwell et al., 2019). The specific calculation formula is:

$$P_i = c_i / T_i \tag{5}$$

Among them, c_i represents the real-time monitoring concentration of water pollution; T_i represents the standard pollution index, and its calculation formula is:

$$T_i = \frac{1}{N} \sum_{i,j=1}^{n} \left(\overline{x}_i - \overline{x}_j\right)^2 \tag{6}$$

Among them, N represents the types of pollutants in the water body; $\overline{x}_i$ represents the comprehensive pollution index; $\overline{x}_j$ represents the average pollution index.

According to the standard pollution index calculated by formula (6), the water quality is classified to obtain the equivalent standard (Kyei and Hassan, 2019), as shown in Table 2.

Table 2 Water pollution level table

Grade	I	II	III	IV	V
Specific value	0–0.2	0.2–0.4	0.4–0.6	0.6–0.8	0.8–1.0

The load intensity of water resource pollution is measured according to the above grade standards. The specific measurement process is as follows:

1 Considering the uncertainty and ambiguity of various factors of water pollution during the measurement process (Gao et al., 2021), establish a set of membership degrees D:

$$D = \{d_1, d_2, \ldots, d_n\} \tag{7}$$

Among them, d_i represents the evaluation criteria of each evaluation factor.

2 To measure the importance of evaluation factors, this paper mainly establishes a weight matrix to calculate the weight of evaluation indicators (Bashar and Fung, 2020):

$$D_k = \sum\nolimits_{i=1}^{N} \log h\left(r_i^t\right) \tag{8}$$

Among them, D_k represents the index weight; h represents the water resource pollution index; r_i^t represents the contribution score of each factor.

3 According to the calculated weight of each evaluation index, a comprehensive evaluation model is established:

$$E_q = D_k \times \frac{[w(t) \times v(t)]}{1 - [w(t) \times v(t)]} \tag{9}$$

Among them, w(t) represents the water quality of the pollution source; v(t) represents the water resource vulnerability coefficient.

4 Finally, according to the comprehensive evaluation model (Paul et al., 2019), the measurement of the intensity of the pollution load of water resource is realised. The specific formula is:

$$K_i = \sum\nolimits_{j=1}^{n} Q_{ij} W_j + p \tag{10}$$

Among them, K_i represents the total load of type i pollutants (natural or man-made pollution) in the overall water resource; j represents the number of different types of pollution sources in the water resource; E_{ij} represents the output coefficient of type i pollutants; W_j represents the specific number of pollution sources of type j; p represents the amount of pollutants input to the water resource brought by the rainfall process.

According to the above analysis, based on the establishment of model database and output coefficient model, the comprehensive pollution index method is used to measure the pollution load intensity of water resource, and the final measurement result is obtained. This method effectively improves the problem of inaccurate measurement results in the traditional single factor evaluation method, and can accurately reflect the water pollution load intensity index.

3 Experimental test

In order to verify the water resource pollution load intensity measurement method based on SWAT model designed above, experimental tests were carried out. The overall experimental scheme is as follows:

3.1 Experimental scheme

1. Experimental data: The data used in the experiment are from the statistical data published by the State Environmental Protection Administration. Multiple experimental areas are selected for the experiment to reflect the comprehensiveness of the experimental results. This paper mainly selects 6 areas as the main research sites, which are uniformly numbered as areas 1–6, among them, the total area of area 1 is 17.5 km^2, the total area of area 2 is 23.4 km^2, the total area of area 3 is 9.1 km^2, the total area of area 4 is 38.0 km^2, the total area of area 5 is 29.7 km^2 and the total area of area 6 is 14.9 km^2. The specific experimental area is shown in Figure 1.

Figure 1 Schematic diagram of the experimental area (see online version for colours)

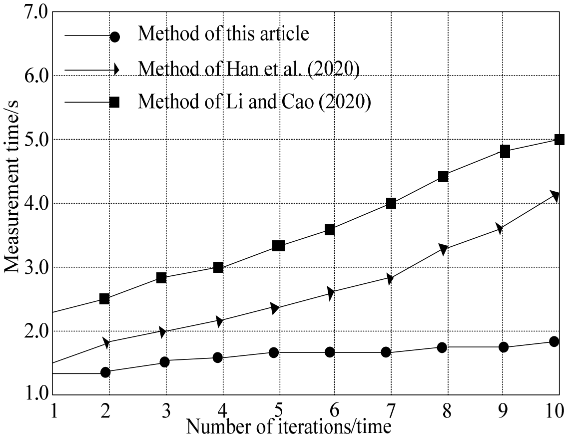
2. Experimental method: In the experimental test, only verifying the method in this paper will lead to the problem of single experimental results and low credibility. Therefore, the Han et al. (2020) method and Li and Cao (2020) method are used as comparative methods for comparative analysis to highlight the advantages and innovation of the method in this paper.

3 Experimental indicators: The time-consuming, deviation of measurement results and measurement range of water pollution load intensity were selected as evaluation indexes. The shorter the measurement time of water resource pollution load intensity is, the higher the overall operation efficiency of the measurement method of water resource pollution load intensity is. The smaller the deviation is, the higher the measurement accuracy is. The smaller the gap between the measurement range of water pollution load intensity and the actual area of the experimental area, the more practical the measurement method will be.

3.2 Experimental results and analysis

The research on water pollution load needs to be handled in a short time to reduce the negative impact of water pollution on human health. Therefore, when measuring the load intensity, take the measurement time as the experimental index, and compare the traditional method with the method in this paper. The results are shown in Figure 2.

Figure 2 Comparison results of intensity measurement time-consuming

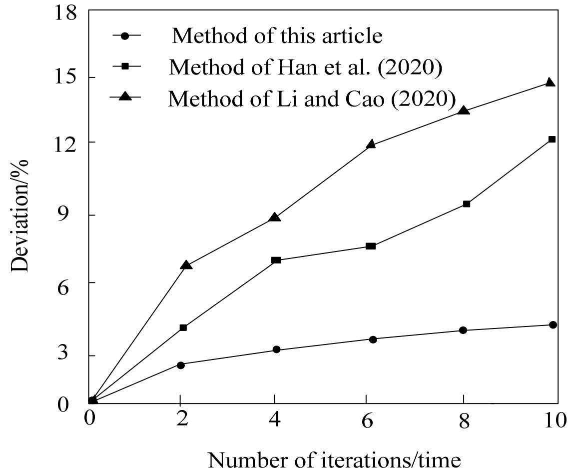


It can be seen from the analysis of Figure 2 that, on the whole, with the increase of the number of iterations, the time-consuming of water pollution load intensity measurement of different methods shows an increasing trend. Through comparison, it can be seen that the measurement time-consuming trend of the method in this paper is not obvious, and the time-consuming is always between 1.0 s–2.0 s, while the maximum time-consuming value of the Han et al. (2020) method is 4.2 s, and the maximum time-consuming value of the Li and Cao (2020) method is 5.0 s. The above values fully show that the water pollution load intensity measurement efficiency of this method is high, and can evaluate the water pollution status in a short time.

The measurement accuracy of water resource pollution load intensity is one of the important indicators to verify the performance of the measurement method, so the measurement deviations of the three methods are compared, and the comparison results are shown in Figure 3.

It can be seen from the analysis of Figure 3 that there is a large gap between the measurement result deviation of this method and the Han et al. (2020) method and Li and Cao (2020) method. Although the measurement result deviation of this method also maintains an increasing trend, it is relatively slow. Compared with the traditional methods, the gap is obvious, and the measurement result deviation of this method always remains below 4%. It can be seen that the measurement result deviation of this method is low and the measurement accuracy of water pollution load intensity is high.

Figure 3 Comparison results of measurement results deviation



Finally, in order to verify the comprehensiveness of the method in this paper, taking the measurement range of water pollution load intensity as the experimental index, different methods are compared, and the results are shown in Table 3.

Table 3 Range of water pollution load intensity measurement/km^2

Experimental area number	*The method proposed in this paper*	*Han et al. (2020) method*	*Li and Cao (2020) method*
1	17.0	16.3	15.9
2	22.9	20.1	19.8
3	8.7	8.5	7.3
4	36.1	34.9	35.0
5	29.4	27.4	26.7
6	14.5	13.1	12.9

By analysing the data in Table 3, it can be seen that the gap between the area that can be measured by this method and the actual area of the experimental area is small, and the maximum gap is only 1.9 km^2, while the gap between the area that can be measured by Han et al. (2020) method and Li and Cao (2020) method and the actual area of the experimental area is large, and the maximum gap is 3.3 km^2 and 3.6 km^2 respectively. It shows that this method can measure the water pollution load intensity in a large area more comprehensively, and the reference value of the measurement results is higher.

4 Conclusions

1. In the context of the rapid development of agriculture, industry and other industries, materials and wastes in the production process will generate a large number of pollutants, which will affect the ecological environment and water resource. Therefore, it is urgent to solve the problem of water resource pollution.
2. In order to effectively prevent and control water resource pollution, the research on water resource pollution load intensity measurement based on SWAT model was proposed to solve the problems of traditional methods such as time-consuming intensity measurement, large error in prediction results of water resource pollution load intensity and small measurement range.
3. The analysis of experimental results shows that the method of water pollution load intensity measure remain the 1.0 s to 2.0 s between takes, water pollution load intensity measurement deviation remain below 4%, and the ability to measure the area and experimental area of the gap between actual area is not large, the experiment results shows that the method of measurement is better.
4. Although the method has made some progress, there is no special study on all kinds of toxic substances in water bodies in the analysis of water resource pollution. Therefore, the detection of toxic substances in water bodies will be the research focus to further optimise the method in this paper.

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