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The Efficiency Simulation of the Performance of a Sequencing Batch Biofilm Reactor for Purification of Domestic Sewage based on the Artificial Neural Network

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Abstract

Today, People's living environment in the rapid development of the industry has become a problem that can not be ignored. In order to alleviate the current situation of water pollution, this paper will make a research on it. The artificial neural network model is established based on the water quality characteristics of the domestic sewage. According to the structure of the model, the experimental device is designed to determine the weight of indicators in domestic sewage, and the experimental study is carried out. By comparing the simulated values and predicted values of 6 groups, then there is the following conclusion: through the system filter, the water quality of the effluent can reach the standard (GB18918 - 2002). A further analysis of the results, the conclusion that the sequencing batch biofilm reactor of the artificial neural network has a better performance in the purification of domestic sewage can be got. In order to guarantee the stability of the system, the performance is evaluated. Then there is the following conclusion: the simulation performance of the system is within the standard error range. The research of this paper has laid a foundation for the development of domestic sewage purification technology.

Keywords

Domestic sewage, Artificial neural network model, experimental device, simulation experiment, sequencing batch biofilm reactor

1. Introduction

Since twenty-first Century, the great economic benefits has greatly promoted the reform and improvement of the level of industrialization. In this environment, the problem of environmental pollution[1] has been put on the agenda and attracts more and more attention. China is a big energy country, water resource is rich, but the per capita water consumption is not optimistic, so the water pollution to rectify is very important. Domestic sewage will not only harm the human health, harm the development of industries such as: animal husbandry, fishery harm agriculture, harm the industrial production, harm the aquatic ecosystem, affect groundwater quality, but also will endanger the interests of individuals and society standard in the economy. It is essential to develop the purification process with good treatment effect, high efficiency, low application cost, and to design a cost-effective domestic sewage purification system that meets the actual situation in China. At present, there is a lot of research and exploration about project design, project investment, construction and operation and management of the sewage plant, the simple evaluation and decision theory is formed. But the theoretical study of domestic water is still lagging behind, and the comprehensive decision making system is not formed[2]. In view of the characteristics that there are heavy metals in the water body, there are following methods: the chemical method, the activated carbon adsorption method, ion exchange method and reverse osmosis method. Membrane reactor is a kind of sewage treatment technology with high efficiency and compact type, which has been widely used in real life. The sequencing batch biofilm reactor has a very important significance in the ability of removing nitrogen and phosphorus. Sequencing batch biofilm reactor is a kind of microbial system composite reactor with the ability of the formation of multiple types of breathing and purification. By filling different fillers, such as fiber, active carbon and ceramsite, multiple trophic ecosystem reactor is constituted. It can provide a micro environment that is good for the purification capacity development of microbial environment. It can remove organic matter containing carbon[3], nitrogen and phosphorus, and also can reduce organic matter and harmful sewage and reduce the extent of groundwater pollution. It provides the technical support and the development basis for the further development of domestic water treatment industry in our country. Intelligent control technology has a very significant reference value in the field of sewage purification. Artificial neural network is a processing method to simulate the large number of neural processing units in the human brain. It has the following characteristics that is similar to the central nervous system of the human brain: input data, interaction, adaptive, self organization and so on. Artificial neural network can provide a way for the simulation process of domestic sewage treatment through its own approximation ability. For biofilm reactor, artificial neural network technology can clear domestic sewage to strengthen the ecological construction, for the development of China's water purification industry, it has brought opportunities.

2. The establishment of artificial neural network model

Artificial neural network is a complex network which uses computer to simulate the neural network architecture and the behavior of the human brain. There are some characteristics: nonlinear, high identification rate, simple method and random[4].

2.1. The principle

There are lots of standards of artificial neural network, BP neural network is one of methods with more typical and more important treatment methods. In order to better use the neural network, this paper, according to the BP neural network algorithm, sets up the following steps:

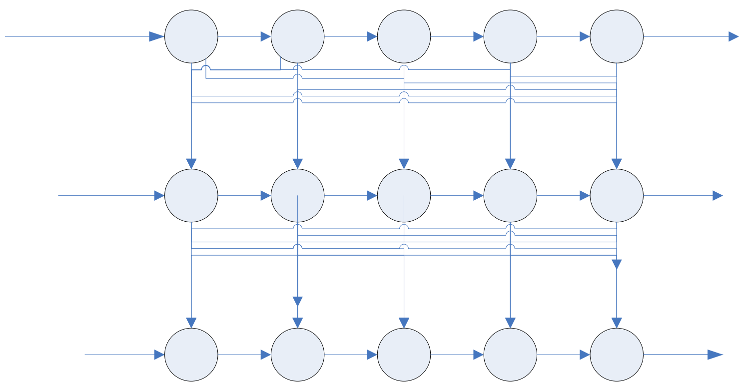

Fig 1. The diagram of the BP neural network structure

The BP neural network is composed of three layers. Hierarchical structure from top to bottom are the top input layer, middle layer and bottom layer. The middle layer can be composed of a multiple simulation layer. The top layer is the level of inputting the information. The bottom layer is filtering information after information processing, in other words, it is also called information layer. The transmission of information is transmitted from top to bottom. In this paper, the information is regarded as a signal, the transmission path is: input layer→hidden layer, hidden layer→output layer. Signal transmission can be realized by forward propagation. Through antipropagation, neural network error can be reduced to a certain extent[5]. In the signal transmission process from the highest level to the lowest level, if the output signal has difference, the propagation descend gradually. By adjusting the weight, system reverses propagation to reduce the error. Taking into account the simplicity, efficiency and accuracy, a few hidden layers are selected in the experiment, such as one layer.

2.2. The determination of weights

In the transmission process, when signal passes three levels, there are errors. The weights between the highest input layer, the middle of the hidden layer, the lowest hidden layer should be considered. Through the analysis of the weight values, whether the signal in the whole system operation is positive or negative can be judged, and the error can be reduced. In this paper, the evaluation standards are average error rate, root mean square error, prediction standard error[6] and correlation coefficient.

Average error rate is expressed by the mean error rate:

$$M = \frac{1}{\mathrm{n}} \sum_{i=1}^{n} \left| x_i - \hat{x}_i \right| / \left| x_i \right| \tag{1}$$

Root mean square error is expressed in the root mean square error:

$$R = \sqrt{\sum_{i=1}^{n} \left(x_i - \hat{x}_i \right) / \sum_{i=1}^{n} \hat{x}_i} \tag{2}$$

The prediction standard error is represented by the standard error:

$$S = \frac{100}{\overline{x_i}} \sqrt{\sum_{i=1}^{n} \left(x_i - \hat{x}_i \right) / n} \tag{3}$$

The standard of correlation coefficient is expressed by correlation coefficient:

$$X^2 = \frac{\sum_{i=1} \left(x_i - \overline{x_i}\right)\left(\hat{x}_i - \overline{\hat{x}_i}\right)}{\sqrt{\sum_{i=1} \left(x_i - \overline{x_i}\right)^2 \left(\hat{x}_i - \overline{\hat{x}_i}\right)^2}} \tag{4}$$

In the above formulas, there are

$$\overline{x_i} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{5}$$

$$\overline{\hat{x}_i} = \frac{1}{n}\sum_{i=1}^{n} \hat{x}_i \tag{6}$$

$\overline{x_i}$ is the actual value of signal, $\hat{x}_i$ is preset value of signal, n represents experimental group number.

The link weight between the input signal and the output signal can be expressed by the following formula:

$$IN = \sum A \cdot \sum B \tag{7}$$

In the above formula, IN indicates the weight value of the input signal, A is the signal from the top layer to the middle layer, and B indicates the weight value of the signal from middle layer to the last layer.

2.3. Network topology structure

In BP neural network[7], the error value between the actual value and the preset value will become smaller with the increase of the middle hidden layer. It reflects inverse variation law, and the research results are more feasible and scientific. In this paper, taking into account the system operation efficiency and accuracy of the double level, the neural network with 3 simulation layers is used. In the experiment, the input layer includes TN、TP、COD、DO、W/D、A/N concentration, The output layer includes TN、COD、TP\、NH_4 concentration. Specific situation is as follows.

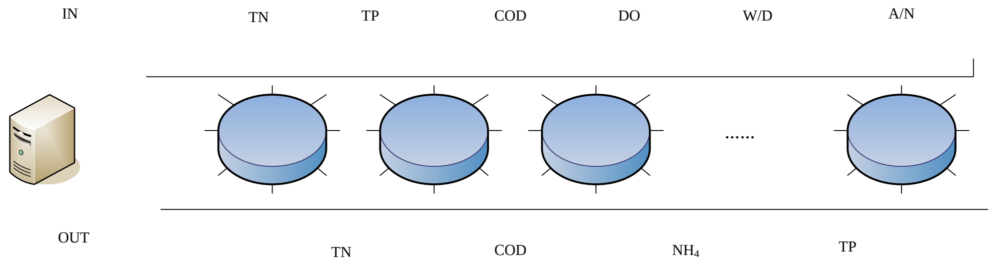

Fig 2. The simulation experiments of BP neural network

Considering the operation of the whole system, factors affecting the learning rate and momentum factor of artificial neural network are in the range of 0 - 1. The learning time factor is optimized by adjusting the number of samples. In this paper, MATLAB software is used to analyze and simulate, the result of the best effect of the system is :

$$n = 1, L = 0.15, M = 0.8, T = 8500$$

n is system operation group number, L is the production value of efficiency during the system operation, M is the concentration value of life index in the process of information transmission, T is learning time.

3. The design of experiment

Simulating the actual situation of domestic sewage treatment in the real life, so in this paper, the data is the basis of the collected data after 30 cycles of the whole experimental system[8].

3.1. Experimental device

A column with a height of 400mm and a radius of 150mm is made. The four layer is filled with soft filling material which is about 40% of the total volume. Each layer is separated by gauze. Among them, the selection of filler has the characteristics of expanding the living area of microorganisms, ensuring the processing efficiency of the system, stable physical properties, low cost and so on. For life sewage in real life, its pH≥ 5. Taking PH value as an example that gram positive bacteria, such as gram negative bacteria and other bacteria in domestic sewage, bacterial positive and negative charges are the same, self carried electric points are not more than 5. In this paper, the selected filling materials are material with soft and semi soft, two kinds of properties, which have positive charge and fishbone shaped structure composite material that radius is

105mm.

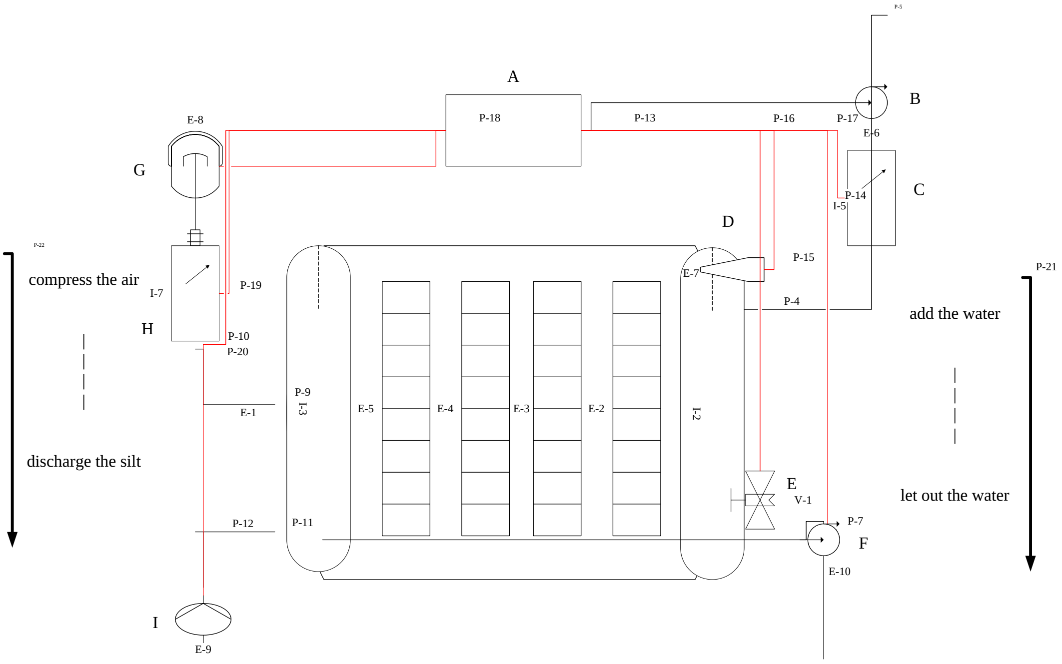

Fig 3. The schematic chart of the SBBR

The left part of the device is the process from aeration to sludge removal, and the right part indicates the process from adding water to yielding water. A is the central coordinator of the whole device collecting data and control system. B represents the water temperature control pump that controls water temperature to maintain a certain degree. C is flow meter of measuring adding water. D is PH value meter for monitoring the water quality of adding water. F is water temperature controller to keep at a certain temperature in control device. G represents wet-pit pump of promoting water removal device. H is air compressor of the introducing air. I is sludge discharge pump of promoting sludge discharge.

By filling material provides attached carrier for micro-organisms, this device can effectively expand the area of microbial habitat, can create an environment that is suitable for the growth and survival of microorganisms, and can promote closely related living environment of microbial growth, reproduction, shedding. It is good for microbial steady growth.

3.2. Wastewater index

The content of domestic wastewater has high nitrogen and high phosphorus. In this paper, the simulation experiment is carried out on the premise of the preliminary simple sewage treatment. The main pollution indexes of domestic sewage in the experiment are as follows:

Table 1. Components of the wastewater

content	Concentration(mg/L)
$MnSo_4 \cdot H_2O$	2.50
$FeSO_4$	12.50
$MgSO_4 \cdot 7\ H_2O$	22.00
NH_4CI	115.00
$CaCI_2 \cdot 2\ H_2O$	30.00
$C_6H_{12}O_6$	540.00
R-CH(NH2)-COOH	215.00
NaCl	85.00
$(C_6H_{10}O_5)_n$	610.00
$NaHCO_3$	850.00
$Na_2H_2PO_4 \cdot 12H_2O$	110.00
$K_2H_2PO_4$	50.00

In this paper, the UV754N spectrophotometer is used[10], the national standard GB11914 - 49 is used. Titration method is adopted. Measurement index is COD_{Ct}. The UV754N spectrophotometer is used, the national standard GB11894—89 is used. Photometric method is adopted. Measurement index is TN. The UV754N spectrophotometer is used, the national standard GB7479—87 is used. Photometric method is adopted. Measurement index is NH_4^+-N. The UV754N spectrophotometer is used, the national standard GB11893—89 is used. Photometric method is adopted. Measurement index is TP. In order to further study the results[11], in this paper, three groups of experimental equipment are set up to dealing with sewage. The concentration range of domestic sewage is

Table 2. Components of the experiment wastewater

content	concentration(mg/L)		
	1	2	3
COD_{Ct}	185.21—220.78	225.21—251.21	270.45—285.65
TN	46.54—55.21	60.58—68.54	78.21—85.65
$NH_3 \cdot N$	48.54—52.57	60.94—68.54	78.98—85.85
TP	6.10—7.21	8.51—8.99	10.24—11.90

According to the results, the concentration of pollutants in the three groups devices are gradually increasing.

3.3. Experimental procedure

The experimental period[12] is assumed to be 12 hours, the adding water time is within 10 minutes. When water is full, aeration is alternated for 1 to 2 hours, until the end of a cycle. Data sample points are taken at 10 o'clock am everyday, after 20 consecutive days, finally average value is got. The operating parameters of the three devices are as follows:

Table 3. The parameters of experimental operation

content		GROUP		
		1	2	3
DO(mg/L)		1.60	2.15	2.62
Aeration time	0——6	2/1	2/2	2/2
	7——12	4/1	2/1	4/1
The ratio of dry and wet		1/3	1/4	1/5
The water quantity		25	28	29

4. The analysis of results

According to the computer simulation and experimental simulation[13], the data of the 6 groups are used as the basis for analysis. Each group is divided into 3 types, the type of difference is: in computer simulation experiments, each indicator is different from the input signal. In the experimental simulation, each index is different as the concentration of the adding water. 1, 2 and 3 represent experimental type.

4.1. Result verification

In the above experiments, the relevant data of the experimental simulation is got, and data statistics are as follows.

From the whole, in the indexes COD, NH_4, TN, TP, the proportion of adding water pollution index value of indexes COD and NH_4 and effluent pollution index value is relatively larger, and the change is smooth. Especially in the first type experiment, the removal rate of index COD reaches 97%, the removal rate of index NH_4 reaches 98%. the proportion of adding water pollution index value of indexes TP and TN and effluent pollution index value is relatively smaller, the change of removal rate of index TN and TP is large. Among them, the highest value of TN reaches 91%, TP reaches 88%. Research standard GB18918 - 2002 shows that the output purified water through the system can meet the needs of the human body. It can be seen that the purification domestic sewage of sequencing batch biofilm reactor based on artificial neural network can achieve a good performance [15].

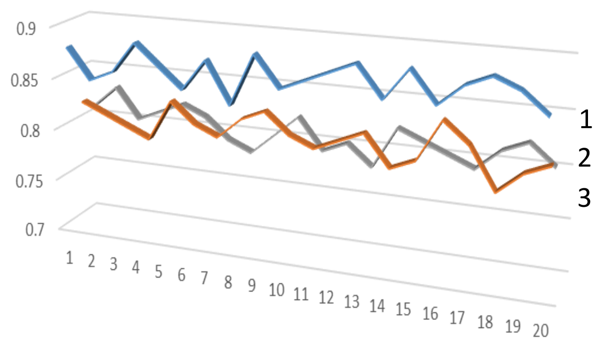

Fig 4. TP removal efficiency in three groups of experimental schematic diagram

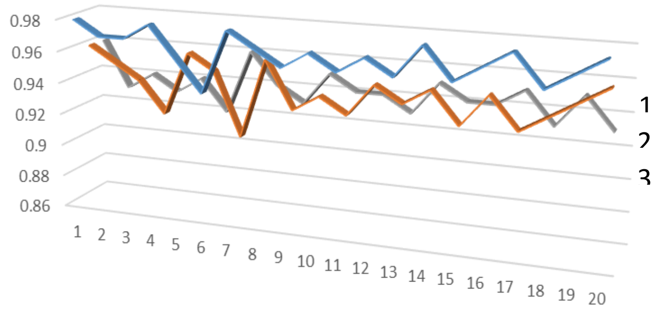

Fig 5. COD removal efficiency in three groups of experimental schematic diagram

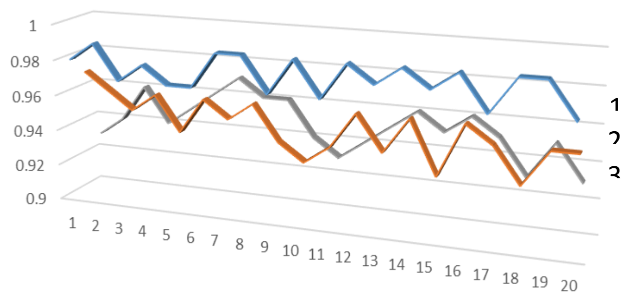

Fig 6. NH_4 removal efficiency in three groups of experimental schematic diagram

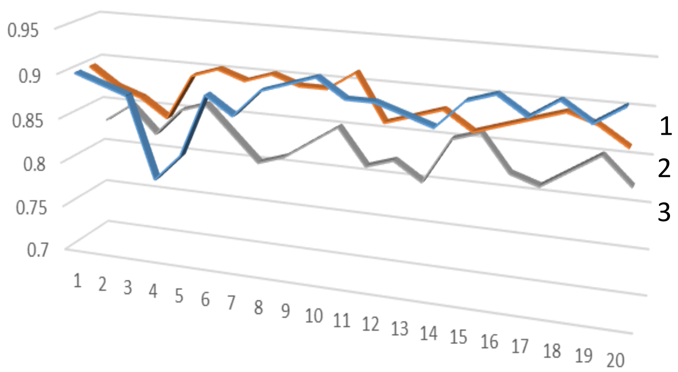

Fig 7. TN removal efficiency in three groups of experimental schematic diagram

The purification domestic sewage of sequencing batch biofilm reactor based on artificial neural network can achieve a good performance, the system runs smoothly and the results are reliable.

4.2. Simulation test

In this paper, the 6 sets of results generated by the experiment are selected, they are compared with artificial neural network simulation, the result is as follows:

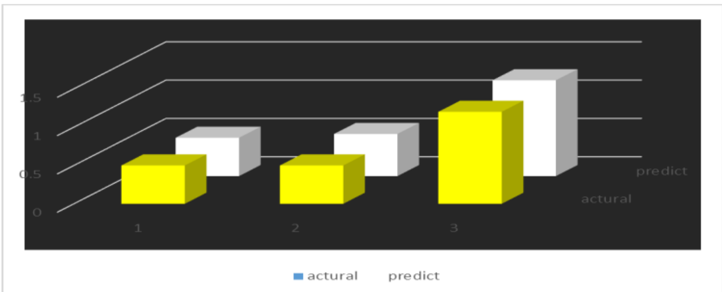

Fig 8. Schematic diagram of NH4 experimental value compared with the simulation values

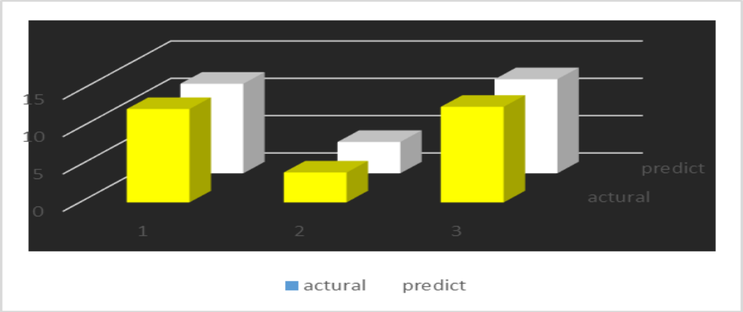

Fig 9. Schematic diagram of TN experimental value compared with the simulation values

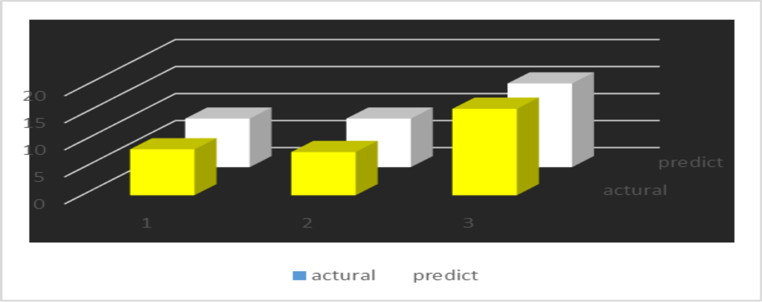

Fig 10. Schematic diagram of COD experimental value compared with the simulation values

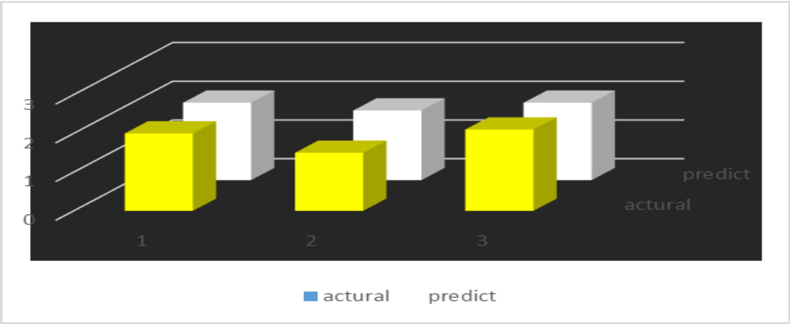

Fig 11. Schematic diagram of TP experimental value compared with the simulation values

By comparing the Predictive value[17] and simulated value of artificial neural networks, the mapping between the predicted data and the simulated data is high. This shows that the precision of artificial neural network is high .

4.3. Result analysis

The simulated data got in the experiment is carried out to simulation, the result is as follows:

Table 4. The relative error results of artificial neural network

Group	NH_4(%)	TN(%)	COD(%)	TP(%)
1	5.34	3.44	10.21	13.23
2	8.54	5.43	7.34	6.43
3	8.56	8.12	5.65	2.32
4	5.43	10.45	9.45	6.90
5	8.56	7.56	2.23	0.89
6	6.43	4.12	4.56	5.67

In the above table, TP in the first group experiment, artificial neural network has the biggest error value 13.23%. In the fifth group experiments, there is a minimum error value 0.89%. In the sixth group experiment, the average error rate of NH4 is 7.45%, the average error rate of TN is 6.65%, the average error rate of COD is 6.56%, the average error rate of TP is 5.98%. All the average error rates are less than 13.23%. The purification domestic sewage of sequencing batch biofilm reactor based on artificial neural network can achieve a good performance.

4.4. Performance evaluation

The experiment is carried out by root mean square error, prediction standard error and evaluation standard of correlation coefficient, the result is shown in the Table 5. Table 4 shows that the maximum error between the simulated and predicted values of domestic sewage is not more than 13.23%. In the above evaluation standard, the prediction standard error is the biggest. Its error is 9.26%. 9.26% is far less than 13.23%. Performance evaluation index of artificial neural network fully proves that the purification domestic sewage of sequencing batch biofilm reactor based on artificial neural network can achieve a good performance.

Table 5. The model test results of artificial neural network

parameter	correlation coefficient	Standard error of prediction	root mean squared error
NH_4	0.9984	9.2563	0.0841
TN	0.9962	7.2594	0.0895

COD	0.9974	6.9512	0.0561
TP	0.9984	4.2159	0.0532

5. Conclusion

Facing the current situation that environment pollution is serious and the water resources problem is serious, in this paper, the intelligent technology is used to deal with domestic sewage and to improve the use efficiency. Through computer simulation and experimental study, the following conclusion is got: indexes NH_4、TP、TN、COD containing poison material is ran through system, the water quality of the effluent can reach the standard. The removal rate of index COD reaches 97%, the removal rate of index NH_4 reaches 98%. The removal rate of index TN reaches 91%, the removal rate of index TP reaches 88%. In the experiment, the change of the removal rate of TN and TP is large, and the change of the removal rate of NH_4 and COD is stable. The simulation experiment shows that the fitting degree of actual value and experimental value is high. the purification domestic sewage of sequencing batch biofilm reactor based on artificial neural network can achieve a good performance. In order to guarantee the stability of the system, the performance evaluation is carried out. The the following result is got: the simulation performance of the system is within the standard error range. The research of this paper has broad prospects for development. It not only provides the whole technology for the purification of domestic sewage, but also it provides the scientific value and practical value for the environmental protection, the sustainable development of the society and the improvement of production efficiency.

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