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Research Article

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Study on water quality prediction model of sewage treatment system

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ABSTRACT

The paper adopted A/O-MBR pilot system as the study object, got a lot of data of the inlet or outlet water quality through water quality monitoring pilot study. With the sample data, this paper established the water quality prediction model of A/O-MBR pilot system by software MATLAB7.1. The water quality prediction model can effectively predict the sewage treatment system dynamic and achieve real-time control, ensured that the system was sustainable, stable and efficient operation.

Keywords: Sewage treatment, A/O-MBR pilot system, Prediction model of water quality, MATLAB7.1，BP neural network.

INTRODUCTION

The water treatment process is multi-input multi-output dynamic system and open system of a large scale, complex structure, many variables, and having some changes in time, space, quantity and sequence. It possesses some characters as follows: the complicated reaction mechanism, multi-input multi-variable, the highly nonlinear, uncertainties and hysteresis on time, space and quantity etc[1]. Therefore, the traditional water quality prediction method due to its own limitations cannot objectively reflect the true state of the water quality.

From the point of view of system theory, this paper selected A/O-MBR pilot system processing campus domestic sewage as the research object. On the basis of its water quality monitoring, the paper used BP neural network modeling its water quality, determining the structure and parameter of the artificial neural network prediction model, and optimized it. At last, the model was verified.

EXPERIMENTAL SECTION

THE MECHANISM OF WATER QUALITY PREDICTION MODEL

The Feasibility of Artificial Neural Network to Predict Water Quality

Artificial neural networks namely neural networks, it is a complex networks which is composed by the extensive connection of a large number of simple processing units. It is proposed on the basis of the achievements of modern biology study of human brain tissue. It is used to simulate the human brain network structure and behavior. Its focus is on the available part which can be used to overcome solve the problem, which the current computer or other systems cannot solve, such as learning, identification, control, expert systems. To sum up, the artificial neural network has the following characteristics:

1）Distributed storage and fault tolerance: Information is stored in the entire network with a distributed manner, not centrally stored in one place. And then each neuron in the network can both stored part of a variety of information. Its advantage is that even if information appears lost, damaged, or error condition, the overall accuracy of the output is not affected; its distributed storage and associative memory function makes the network has the features of fault tolerance and robustness. Meanwhile, the fault tolerance feature of human brain is an important form of wisdom [2].

2）Massively parallel processing: Artificial Neural Networks in the structure are parallel, and each unit of the network can be a similar process, therefore, the network is the information processing unit in a large number and has a level parallel manner, with high computing speed [3].

3）Self-learning, self-organization and self-adapt ability: Neural network is a variable structure system [4]. There is a variety of connections between neurons and the connections strength between neurons has a certain plasticity. The network can meet the requirements of different information processing by learning and training through the network self-organization, thus completing the environmental change adaptation and learning ability of external things [5].

4）Nonlinear Dynamic Systems: Neural network is the collective behavior of a large number of neurons, but not only a simple sum of each neuron behavior. So it shows the general characteristics of complex nonlinear dynamic systems with strong nonlinear processing capabilities.

5）Dealing with complex systems: Neurons can deal with some problems which the environmental information is very complex, background knowledge is not clear and inference rules do not explicitly clear. In dealing with complex systems, it can learn to deal with specific examples through the learning of neural network (in accordance with the laws of learning), and then it can give the satisfactory answer [6].

Neural networks have the potential for intelligent control systems, because of its capabilities of self-learning and adaptation, self-organization, nonlinear dynamics and massively parallel processing. Over the past decade, the neural network has been widely used in pattern recognition, image processing, system identification, optimal predictive, adaptive control and other fields.

Basic principles and structure of BP Network

Error Back Propagation Network namely BP neural network, it is a multilayer feedforward neural network. BP neural network has the advantages of simple structure, stable working conditions and easily implemented in hardware.So it is widely used in nonlinear mapping, complex systems simulation, etc, and it is currently the most widely used artificial neural networks.

BP neural network is a typical multi-layer structure, it is composed of one input layer, one output layer and one or more hidden layers and the layers were all interconnected. But the units in the same layer did not exist connection between each other [7], the network structure was shown in figure 1.

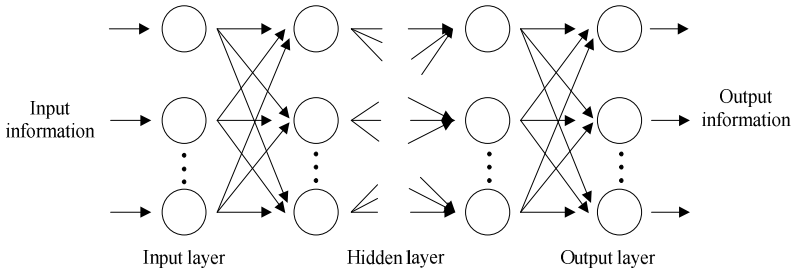

Fig 1: Structure of BP neural network model

The input and output layers, respectively which means that the network input and output variables, the hidden layer was used which means that the interaction between the input processing unit. As the input signal, it usually propagates forward to the hidden layer the first, then after role function, the information of the hidden layer node disseminate to the output layer, and finally get the output results. Number of neurons in the input layer and output layer is determined by the practical problems and the number of neurons in the hidden layer is determined based on the empirical formula or network debugging. It is the determination of neural network that to determine implied layers, each layer of neurons and neuron connection.

ESTABLISH OF WATER QUALITY PREDICTION MODEL

Through a series of optimized design and cycle trial, with the sample data, established the water quality prediction model of A/O-MBR pilot system by software MATLAB7.1 [8].

Determination of Samples Data

According to the monitoring data obtained by experiment, selected COD_{Cr}、NH_3-N、TN、TP、DO value of Aerobic tank and MLSS value of Aerobic tank as the input value. Besides ,the values of outlet water,COD_{Cr}、NH_3-N、TN and TP ,as the output value.There were 30 sets of data after excluding two obvious error data [9]. With this sample, the water quality prediction model of A/O-MBR pilot system can be established.

To improve the accuracy of network training and reduce the errors of test, each input and output data was normalized in range of [-1, 1] by premnmx function in this paper. Forecast samples were normalized simply by tramnmx function which was corresponding with premnmx function.

Determination of the Number of Network Layer and Nodes Number of Hidden Layer

According to the general requirements of BP neural network, there was one hidden layer in the network. The accuracy of network training was improved by adding the node number of hidden layer. Therefore, the prediction model of neural network was a three-layer neural network with a hidden layer.

The optimal node number of hidden layer was selected by the combination of empirical equation and trial-and-error method. Because there were 6 neurons in input layer and 4 neurons in output layer, according to the empirical equation, the nodes number of hidden layer should be in range of 5 to 16 in the model. While the network of the model was trained, maximal iteration was set at 10000, target error was 0.001 and learning precision was 0.1. After repeated training, the node number of hidden layer was 12.

Topological Structure of Network Model

The prediction model of A/O-MBR pilot system adopted an input layer, a hidden layer and a output layer, namely three-layer BP NN model. There were 6 neurons in input layer and 4 neurons in output layer and the nodes number of hidden layer were 12. Topological structure of prediction model is shown in Figure 2.

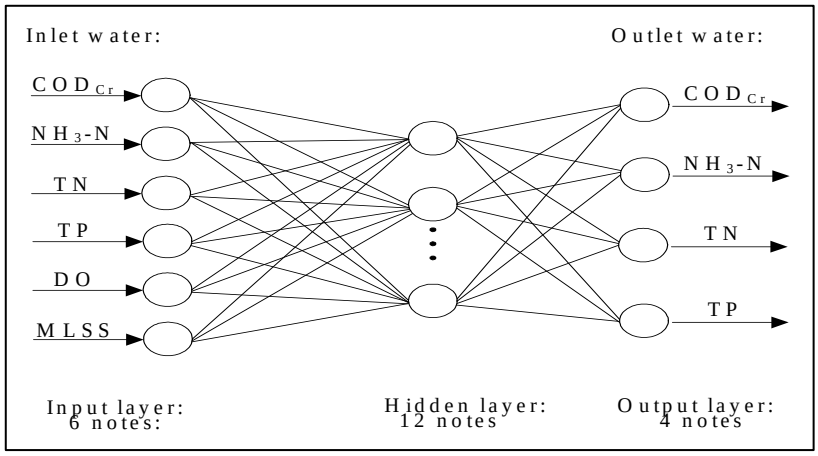

Fig 2: Topological structure of A/O-MBR Pilot system prediction model

Determination of Network Parameters

Node Transfer Function: The S-transfer function was used in the hidden layer neuron of BP neural network. In this paper, the transfer function of hidden layer adopted tansig function and output layer adopted purelin pure linear transfer function [10].

Initial Value of Network: The initial value of network must be set up before training BP neural network. The newff function which initialized the weight and threshold of network automatically was used to build network frame in this paper.

Learning Algorithm of Network: Some frequently-used functions like self-adapting gradient descent traingdx, elastic gradient descent trainrp, Fletcher-Reeves conjugate gradient descent traincgf, quantify conjugate gradient descent

trainscg and self-adapting gradient descent traingda etc, and were obtained to train the network. We came to the conclusion that when used quantify conjugate gradient descent trainscg to train the model, the convergence rate and fitting ability of the network were better than other functions.

Table 1: 23th ~ 30th groups of test sample error

Item	Found	Model output value	Absolute error	Relative Error（%）	Item	Found	Model output value	Absolute error	Relative Error（%）
23th test samples					24th test samples				
COD_{Cr}	10.4	12.61	2.21	21.23	COD_{Cr}	21.8	17.14	4.66	-21.38
NH_3-N	2.17	2.34	0.17	7.93	NH_3-N	2.98	2.34	0.64	-21.56
TN	17.5	22.52	5.02	28.67	TN	23.0	17.51	5.49	-23.88
TP	2.25	2.21	0.04	-1.78	TP	2.83	3.32	0.49	17.31
25th test samples					26th test samples				
COD_{Cr}	10.5	10.18	0.32	-3.07	COD_{Cr}	13.5	17.20	3.70	27.4
NH_3-N	2.36	2.16	0.20	-8.47	NH_3-N	2.25	2.43	0.18	8.22
TN	23.9	26.74	2.84	11.88	TN	30.1	26.72	3.88	-11.23
TP	2.46	2.21	0.25	-9.97	TP	3.95	3.11	0.84	-21.17
27th test samples					28th test samples				
COD_{Cr}	16.3	16.10	0.20	-1.22	COD_{Cr}	12.3	14.09	1.79	14.56
NH_3-N	2.97	3.09	0.12	4.21	NH_3-N	2.02	1.72	0.30	-14.63
TN	13.8	15.51	1.71	12.41	TN	24.1	18.90	5.20	-21.58
TP	2.66	2.61	0.06	2.26	TP	2.78	3.41	0.33	22.67
29 th test samples					30th test samples				
COD_{Cr}	11.7	11.07	0.63	-5.36	COD_{Cr}	14.5	16.89	2.39	16.48
NH_3-N	1.85	2.04	0.19	10.50	NH_3-N	2.31	2.70	0.39	16.88
TN	12.9	15.05	2.15	16.67	TN	19.8	17.08	2.72	-13.74
TP	3.53	3.40	0.13	-3.71	TP	3.36	3.04	0.32	-9.44

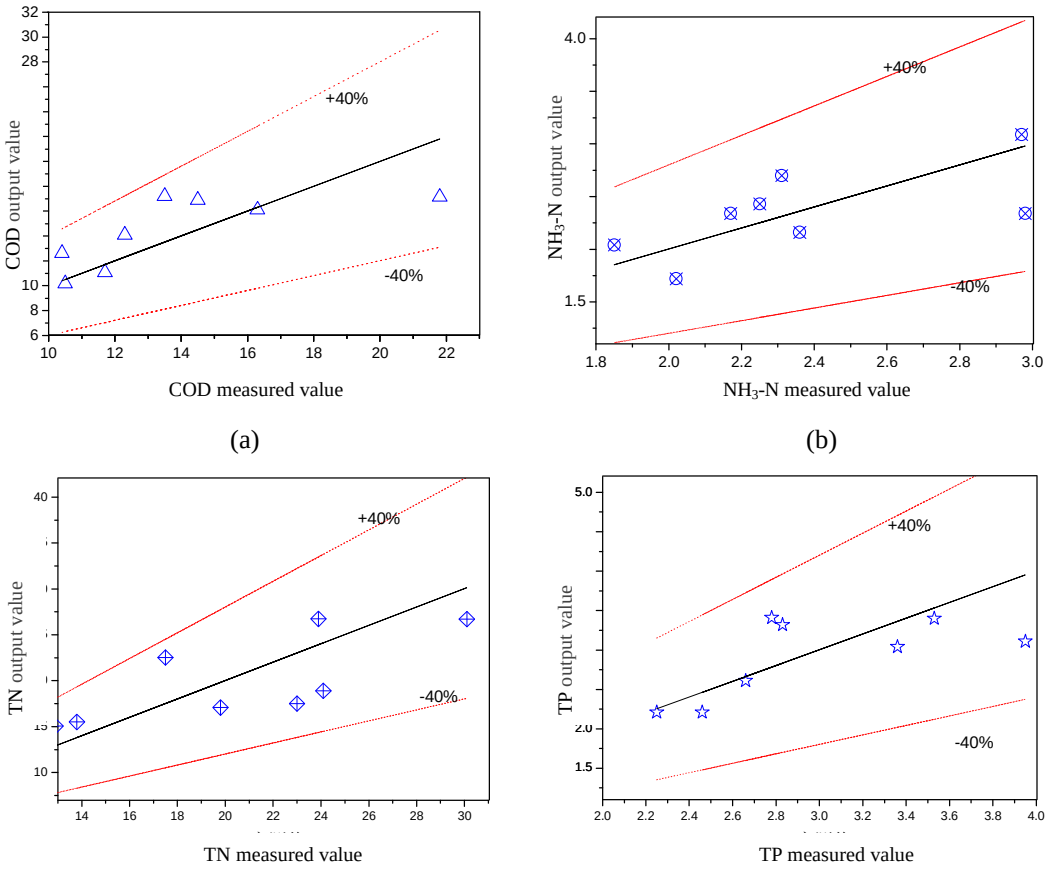

Fig 3:23~30 groups of test sample comparison chart of measured values and model output values

Training and Test of Neural Network Models

The prediction model was trained by software MATLAB 7.1. Using trainscg function as training function, the maximum number of learning was set at 10000, target error was 0.001 and learning precision was 0.1.

Results showed that: network reached accuracy after 191 training, training error was 0.000999037 and target error was 0.001. In this paper, 23th to 30th sets of data as a test sample to test the accuracy of trained network meets the accuracy requirements or not. Obtained 8 sets of model output value of the test samples, then compared the values with the found of sample data, the results were shown in table 1 and figure 3 (a~d).

According to the table 1and figure 3 (a~d), in 8 tested samples , predicted and measured value of COD_{Cr} and TP was closest to each other, but relative error of the NH_3-N and TN was slightly larger. The relative errors of COD_{Cr} ,TP ,NH_3-N and TN were respectively 1.22%~27.4%、4.21%~21.56%、11.23%~28.67%、1.78%~22.67%。

Analysis of Test Results of the Network Model

According to the model training examination result, the relative error scope of the model of 8 examine sample is 1.22% ~28.67%, as know of the consult correlation literature material [11] , in the process of using the BP neural network carries on the simulation forecast, as use the examination sample examine the model, when it's relative error lower than 30%~40%, the training result can be accepted and the network training effect is also good, the model can simulate the relations of pollutant elimination in the analogous system normally. The model forecast relative error was smaller than 28.67% in this article, the forecast error can be acceptted in the scope, therefore,with the success of network trains, the network performance satisfied the request of practical application.

CONCLUSION

This paper adopted the A/O-MBR pilot system as the research object, and got a lot of the water quality data through water quality monitoring pilot. From the viewpoint of system theory, on the basis of the water quality of the data obtained, using the BP neural network constructed the A/O-MBR pilot system water quality prediction model and the effluent COD and NH_3-N, TN and TP concentrations was forecasted, effectively predicted the dynamic work of wastewater treatment system, so as to realize the real-time control.

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