Research on FNN Evaluation of Rural Drinking Water Quality in Mingshan District

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***Abstract* - A new hybrid fuzzy neural model capable of learning and processing fuzzy information in water quality evaluation was obtained by coupling fuzzy theory with neural network model, Fuzzy Neural Network, FNN. The water quality of underground sources in 42 rural areas in Mingshan District in Ya'an City was evaluated based on computer simulations and network training of the data in water quality Gradeification standard. It turns out that No.11out of 42 water sources in Mingshan District belong to Grade IV, No.2 out of them belong to Grade V, and the major hazard indexes were nitrate and Fe.**

Keywords - FNN; Data Simulation; Water Quality Evaluation; Rural Drinking Water; Mingshan District.

I. INTRODUTION

Water quality evaluation is an important part of environmental management and decision making. It is a model to establish water quality Gradeification on the basis of water quality standard and to determine water quality grade [1] so as to determine its pollution level, thus providing a scientific basis for the protection and management of drinking water sources' quality. At present, the main methods to evaluate water quality are Synthetical Index Method [2], Grey Relational Analysis [3], Matter--Element and Extension [4], Fuzzy Comprehensive Evaluation Method [5], Artificial Neural Network Method[6] and so on. And there are both advantages and disadvantages studying water quality evaluation methods from different aspects. The process of water quality evaluation involves plenty of complex phenomena and interactions of multiple factors, as well as a large number of fuzziness and uncertainty. The fuzzy theory is able to handle fuzzy information and make judgments and decisions on water quality, but it does not have the learning function, so it can't learn fuzzy and uncertain information existing in the water quality evaluation system. However, the neural network has the ability of nonlinear mapping and self-learning, but it cannot handle and describe fuzzy information. Based on fuzzy theory and neural network method, this paper construct hybrid FNN and apply it to evaluate the water quality of rural water sources in Mingshan District in Ya'an City.

II. MATERIALS AND METHODS

A. Sample Collection and Detection

By taking geology, topography, geomorphology, hydrology, drainage and underground drinking water distribution into consideration, drinking water samples were collected drinking water samples from 42 villages of Mingshan District in Ya'an City in 2010. Related indicators in 42 water samples were detected according to Standard Examination Methods for Drinking Water (GB 5750-2006). Besides, based on the newly promulgated Standards for Drinking Water Quality（GB5749-2006), Fe, Cr(6+), fluoride and nitrate were finally picked as the water quality evaluation indexes of rural water sources in Mingshan District by combining with related analysis of water quality hazard indexes of Mingshan District [7-8]. The detected concentration values of indexes were shown in Table I.

TABLE I DETECTED VALUES FOR RURAL DRINKING WATER IN MINGSHAN

No.	Fe	Cr(6+)	Nitrite	Fluoride	No.	Fe	Cr(6+)	Nitrite	Fluoride
1	0.04	0.04	11.73	0.97	22	0	0.05	70.44	0.29
2	0	0.05	37.53	0.34	23	0.01	0.05	30.42	0
3	0	0.05	11.86	0.88	24	0	0.05	6.42	0
4	0.21	0.06	4.95	1.50	25	0	0.06	3.47	0.05
5	0	0.06	8.95	0.23	26	0	0.04	9.93	0.14
6	0.02	0.05	47.32	0.20	27	0	0.06	11.87	0
7	0	0.06	7.18	0.49	28	0	0.04	12.73	0.05
8	0	0.03	1.68	0.24	29	0	0.08	28.20	0.16
9	0.13	0.03	5.70	1.40	30	0.02	0.02	13.85	0.05
10	0.07	0.06	5.67	1.16	31	0	0.03	4.40	0.03
11	4	0.11	17.50	0	32	0.06	0.07	19.11	0.24
12	0	0.11	27.32	0.40	33	0.17	0.06	29.33	0
13	0.08	0.12	11.20	0.24	34	0.02	0.02	30.07	0
14	0.01	0.03	35.32	0	35	0.48	0.14	1.18	0
15	0.01	0.08	9.16	0	36	0.02	0.10	20.16	0.04
16	0.18	0.05	5.38	0	37	0.05	0.05	65.30	0.24
17	0.20	0.11	1.20	0	38	0.03	0.08	69.24	0.05
18	0.59	0.11	1.24	0	39	0.02	0.06	67.51	0.36
19	0.01	0.15	44.95	0.12	40	0.02	0.04	37.51	0.76
20	0	0.02	39.26	0	41	0.04	0.02	37.02	0.34
21	0.03	0.10	9.87	0.27	42	0.01	0.03	17.02	0.31

B. FNN

Assuming the input node is n, the output value of the FNN is y[9],

$$y=\frac{\sum_{i=1}^{m}\left[\left(a_0^i+\sum_{j=1}^{n}a_j^i x_j\right)g\prod_{j=1}^{n}f_j^i(x_j)\right]}{\sum_{i=1}^{m}\prod_{j=1}^{n}f_j^i(x_j)} \quad (1)$$

Then in this formula, x_j is the network input; f^i_j is the membership function; a0, a1, a2, ..., aj are model coefficients.

When FNN is used to calculate, the error between the network output and the expected output should be used to modify the model coefficients and the membership function model parameters, so the output of FNN is approaching the true output value [10-11].

Gaussian function [12] is used to calculate the membership function.

$$f_i^j=e^{-\frac{(x_j-c_i^j)^2}{b_j^i}} \quad (2)$$

where c^i_j and b^i_j are model parameters.

Model coefficients modification is calculated according to the following formula [9].

$$a_j^i(k)=a_j^i(k-1)-\frac{\alpha(y_d-y_e)w^i}{\sum_i^m w^i g x_j} \quad (3)$$

$$w^i=f_i^j=e^{-\frac{(x_j-c_i^j)^2}{b_j^i}} \quad (4)$$

In this formula, yd is the expected output of network; ye is the actual output of network; α is the initialization parameter value, taking 0.05.

The model parameters are modified according to the following formula:

$$c_j^i(k)=c_j^i(k-1)-\beta\frac{\partial(y_d-y_e)}{\partial c_j^i} \quad (5)$$

$$b_j^i(k)=b_j^i(k-1)-\beta\frac{\partial(y_d-y_e)}{\partial b_j^i} \quad (6)$$

In this formula, β is the initialization parameter value, taking 0.001.

III. RESULTS AND ANALYSIS

A. Data Simulation of Water Quality Gradeification Standard

When FNN was used to evaluate water quality, the water quality Gradeification standard needs to be used as a training sample to modify the parameters and coefficients of the model. Because it was difficult to obtain the standard data of water quality Gradeification, uniform interpolation method was adopted in the data simulation of Gradeification standard according to the conventional indicators of drinking water in newly promulgated Standards for Drinking Water Quality (GB5749-2006) and their limiting values (see Table II).

TABLE II WATER QUALITY GRADEIFICATION STANDARD

Grade	Fe	Cr(6+)	Nitrite	Fluoride
I	0.1	0.005	1	2
II	0.2	0.010	1	5
III	0.3	0.050	1	20
IV	1.5	0.100	2	30
V	3.0	1.000	3	50

In the data simulation of water quality Gradeification standard, the limiting values of Grade I~IV water were assigned to 1-5 respectively. Suppose that simulation from Grade j to Grade (j+1) generates N water quality Gradeification standard data, then the generative formula of t (water quality Gradeification standard data) is:

$$x_i^k = B_{ij} + \frac{B_{i(j+1)} - B_{ij}}{n}, k = 1,2,3\cdots,n \quad (7)$$

$$t_k = j + \frac{1}{n} \quad j = 1,2,3,4; k = 1,2,3\cdots,n \quad (8)$$

In this formula, x^k_i is the simulation value of the index in group k, item i. B_{ij} is the limiting value of Grade j in the index of item i; t_k is the grade value of water quality in group k. According to formula (7) and (8), 250 sets of data can be obtained through the calculation of related data on table 2.50 sets of data less than that in Grade I, Grade I-II, Grade II-Grade III, Grade III-Grade IV, Grade IV-Grade V were chosen. And then 200 sets were randomly chosen as the training data, while the remaining 50 sets as test data.

B. Network Training and Water Quality Evaluation

When FNN was used to evaluate water quality of rural water sources in Mingshan District in Ya'an City, Fe, nitrate and other two index data were selected as input, and the grade values of water quality were also chosen as input. Besides, the network's input node was set as 4, the output node as 1, and at the same time 5 sets of model coefficients were set as ai to a4 respectively. Firstly, coefficients aii to a4 and the model parameters b, c were randomly initialized, after that, a set of network training data xi was inputted. Then training data xi was normalized through the map, min and max functions in Matlab. The network predicted value yc can be obtained based on formula (1) and (2), and the error between YC and expected output yd were analyzed. Model coefficients all to A4 and model parameters b,c were modified according to formula (3) to (6). Such process was repeated for 500 times and finally the error prediction of 50 sets of test data can be done with a fully trained network model.

According to Fig. 1, the margin of error in predicting grade value was [-0.113 1, 0.102 8], which was within the range of permitted errors.

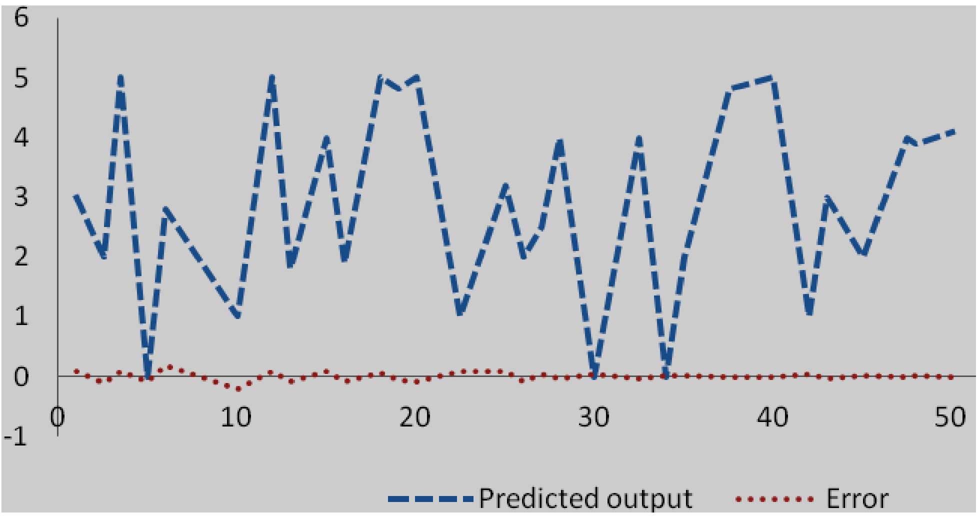

Fig. 1 Error Analysis of Water Quality Prediction for Detected Datum

Water quality of water sources from 42 villages in Mingshan District was evaluated by using the trained network model. According to Table 3, out of 42 rural water sources in Mingshan District, water quality of No. 4, No. 6, No.22, No.35, No.37, No.38, No.39, No.40 and other 3 water sources belong to Grade IV, mainly because of excessive nitrate; and water quality in No.11 and No.18 belong to Grade V, mainly because of excessive Fe content.

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TABLE III. EVALUATION RESULTS FOR RURAL DRINKING WATER IN MINGSHAN DISTRICT

No.	Grade value	Evaluation results	No.	Grade value	Evaluation results	No.	Grade value	Evaluation results
1	2.47	III	15	1.66	II	29	2.62	III
2	2.97	III	16	1.25	II	30	2.13	III
3	2.10	III	17	0.42	I	31	1.87	II
4	3.20	IV	18	4.91	V	32	2.42	III
5	1.79	II	19	3.00	III	33	2.61	III
6	3.16	IV	20	2.85	III	34	2.62	III
7	1.70	II	21	1.85	II	35	1.86	IV
8	1.67	II	22	3.73	IV	36	2.32	III
9	3.26	IV	23	2.61	III	37	3.63	IV
10	2.87	III	24	1.31	II	38	3.59	IV
11	4.78	V	25	1.87	II	39	3.72	IV
12	2.70	III	26	1.88	II	40	3.19	IV
13	1.94	II	27	1.94	II	41	2.98	III
14	2.75	III	28	1.99	II	42	2.39	III

The major cause of excessive nitrate in underground drinking water was related to agricultural non-point source pollution and substandard waste water discharge of factories in cities and towns. Nitrate pollution in groundwater is an increasingly serious environmental problem. Therefore, relevant departments should take appropriate measures to prevent further deterioration of groundwater, to conserve, protect and strictly disinfect water sources, such as reasonable fertilization, formula fertilization, industrial waste water and domestic sewage treatment and so on. The spatial distribution characteristics of Fe in underground drinking water were closely related to factors like regional soil parent material, soil type, human activities and so on. Fe in rural underground drinking water in Mingshan District was positively correlated with the available Fe in soil while negatively correlated with soil's pH. The major soil types in Mingshan District were purple soil and yellow loam, the major soil type of No.11 and No.18 water sources (with excessive Fe content) was yellow loam. At the level of 0.01, yellow loam's pH was significantly lower than that of purple soil[13], while its available Fe content was significantly higher than that in purple soil. Influences of human activities such as urban industry, urban garbage, waste water discharge and so on also intensify the excessive Fe content in underground drinking water.

IV. CONCLUSION

A hybrid fuzzy neural model is obtained by coupling fuzzy theory with neural network. It can not only learn the fuzzy information in water quality evaluation system, but also make judgments and decisions on model information, leading to more scientific and reliable results. FNN was applied to evaluate the water quality of 42 rural water sources in Mingshan District in Ya'an City, thus leading to scientific and reliable results, which can provide a scientific basis for the management of source water quality to relevant departments in Mingshan District. This shows that FNN does have certain applied value in water quality evaluation.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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