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Research Article

Comparative Study on Two Kinds of Evaluation Models of Heavy Metal Pollution in Soil

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Abstract: Heavy metal pollution is an important factor to destroy the food cultivation soil environment and directly or indirectly endanger people's food safety and healthy diet. In this study, two methods are used to evaluate soil heavy metal pollution: The first method is to establish the Nemerow index model, the degree of heavy metal pollution in urban soil is analyzed and evaluated, the Nemerow comprehensive pollution index shows the pollution level; the second method uses FIS and correlation function of MATLAB software, combined with fuzzy comprehensive evaluation method to establish the membership function of Hg and other 6 kinds of soil heavy metal pollution factors. Through the normalization of Matlab-FIS-sugeno model weights, make the membership function adapt fuzzy comprehensive evaluation of weighted fuzzy operator. Thus, we establish the fuzzy comprehensive evaluation model of heavy metal pollution in soil based on Matlab-FIS-sugeno. Respectively, using these two models to evaluate the heavy metal pollution in agricultural soils of Tongling area, the results were consistent with the actual situation.

Keywords: Fuzzy comprehensive evaluation, Matlab, Nemerow comprehensive pollution index, soil heavy metal pollution

INTRODUCTION

With the development of mineral resources which lead to the destruction of natural resources, the soil heavy metal pollution become increasingly serious environmental problems, soil pollution of heavy metals enriched in the human body through the food chain and finally damage people’s healthy diet (Sun, 2007). Soil heavy metal elements mainly include mercury, cadmium, chromium, lead, arsenic, zinc and other elements. The pollution of heavy metals in soil is often contaminated and the effect of different metal elements on the ecological environment is different (Liu and Yangguo, 2007).

Traditional single factor evaluation of the pollution degree evaluation method can only give the monitoring points of a heavy metal factor is excessive and over standard rate, but can not give quantitative soil environmental quality comprehensive evaluation results (Duan and Huanxing, 2010). Therefore, in this study, we use the Nemerow comprehensive pollution index method and fuzzy comprehensive evaluation method to study heavy metals in the soil and construct the evaluation model of Tongling area. We analyze and compare the results and the results are in line with the actual situation (Guan and Yujuan, 2001).

NEMEROW COMPREHENSIVE POLLUTION INDEX EVALUATION METHOD

Nemerow index method is one of the most commonly used methods for the calculation of comprehensive pollution index, which is a new comprehensive evaluation index based on the theory of discrete mathematics. First, we should determine the background value of the soil, that is the chemical elements and compounds content which are not affected by human pollution in the natural environment (Siegel, 1995). Factors affecting soil background values are very complex, including tens of thousands of years of human activities combined effects, the influence of organic matter content and so on. Therefore, soil background values are a range of values, rather than a determined value (Jim, 1998). After investigation, the soil environmental background values in Tongling area are shown in Table 1.

Meanwhile, after investigation we have obtained the measured values of heavy metals in soil in Tongling, which is shown in Table 2.

First, by formula (1), the different points of the different heavy metals of the single factor Nemerow index were calculated:

$$P_i = C_i / S_i \tag{1}$$

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Table 1: Soil environmental background values in tongling mg/kg

Hg	Cd	As	Pb	Cu	Zn
0.05	0.09	12.44	47.81	32.15	85.58

Table 2: Heavy metal contant in soil mg/kg

Sampling point	Hg	Cd	As	Pb	Cu	Zn
1	0.071	1.22	16.9	81.2	76	136.5
2	0.076	0.14	11.2	23.2	28.3	58.8
3	0.071	1.12	21.5	74.3	81	136
4	0.108	0.67	14.9	91.3	76.9	188.6
5	0.096	1.11	17.9	80.5	71.5	195.5

Table 3: Single factor Nemerow index of heavy metals in soil mg/kg

Sampling points	Hg	Cd	As	Pb	Cu	Zn
1	1.42	13.55	1.35	1.69	2.33	1.59
2	1.52	1.54	0.90	0.48	0.86	0.68
3	1.42	12.44	1.72	1.55	2.51	1.88
4	2.16	7.48	1.97	1.90	2.39	2.20
5	1.92	12.33	1.43	1.68	2.20	2.28

Table 4: Weight value of heavy metal pollution elements

Hg	Cd	As	Pb	Cu	Zn
3	3	3	3	2	2

Table 5: Nemerow comprehensive pollution index of different sampling points

Sampling point	1	2	3	4	5
Nemerow index	9.9688	1.2978	9.1937	5.7326	9.1294

In the formula, C_i is the measured value of single heavy metal content, S_i is the soil environmental background value. After calculation, the single factor Nemerow index of different elements of 1-5 sampling points are shown in Table 3.

As the single factor Nemerow index can not accurately display the degree of land pollution, so we use the comprehensive Nemerow pollution index to evaluate:

$$P_{iavg} = \frac{\sum_{i=1}^{n} w_i P_i}{\sum_{i=1}^{n} w_i} \tag{2}$$

$$P_i = \sqrt{\frac{P_{iavg}^2 + P_{i\max}^2}{2}} \tag{3}$$

In the formula,

P_{iavg} = The weighted average of the single factor index
P_{imax} = The maximum value of single factor Nemerow index
w_i = The weight
P_i = The Nemerow comprehensive evaluation index

The single factor index obtained by average value is not accurate, so the average value can be improved by using the weighted average. The weights are classified as shown in Table 4.

After calculation, the comprehensive Nemerow evaluation index of the 1-5 sampling points is shown in Table 5.

According to the evaluation criteria of Nemerow comprehensive pollution index, the sampling point 2 is light pollution and the other sampling points are heavy pollution, the evaluation results are consistent with the actual results.

FUZZY COMPREHENSIVE EVALUATION METHOD

With the deepening of environmental quality assessment, the variables need to study are increasing and becoming more and more complex. There are not only the determined change rules, but also the random change rules. The accuracy and fuzzy of the environmental quality, determination and uncertainty are all characteristic of quantity. So we use fuzzy comprehensive evaluation method to evaluate the degree of heavy metal pollution in soil. The so-called fuzzy comprehensive evaluation method is the application of fuzzy transformation principle and maximum membership principle, it considers the influence of the factors related to the things to be evaluated. Therefore, the fuzzy evaluation model of farmland soil in Tongling mining area is proposed by using the FIS tool in MATLAB software and the model is applied to evaluate the heavy metal pollution in farmland soil in Tongling mining area (Lu and Lu, 2003).

First of all, we need to determine the factors to be evaluated, this study established the factor sets of six elements: Hg, As, Cd, Pb, Cu, Zn. Then we should determin the standard values of the different factors and set up the evaluation set. Because of the soil heavy metal evaluation index has a certain regional, we refer to the soil environment quality standard (GB15168-1995) and the Tongling city soil ring background value, the soil heavy metal pollution is divided into five levels (Zhang and Wang, 2003), as shown in Table 6.
Secondly, we should determine the weight set:

$$S_i = (S_1 + S_2 + S_3 + S_4 + S_5)/5 \tag{4}$$

$$W_i = \left(\frac{C_i}{S_i}\right) / \left(\sum_{i=1}^{n} \frac{C_i}{S_i}\right) \tag{5}$$

In the formula, S_i is the average value of some kind of pollutants and C_i is the measured concentration of some kind of pollutants. After calculation, the grading average values of six kinds of heavy metal pollutants are shown in Table 7.

Table 6: Grading standard of heavy metal pollution in soil mg/kg

Factor	Clean	Relatively clean	Light pollution	Pollution	Heavy pollution
Hg	0.05	0.086	0.15	0.65	1.5
Cd	0.074	0.12	0.2	0.8	3
As	9.2	12.44	15	25	30
Pb	23.6	32.52	50	250	500
Cu	20	32.15	45	100	400
Zn	67.7	85.58	100	350	500

Table 7: Grading average values of different metal elements

Metal element	Hg	Cd	As	Pb	Cu	Zn
S_i	0.49	0.84	18.33	171.22	119.43	220.62

Table 8: Weighted sets of different sampling points

Weight	W_{Hg}	W_{Cd}	W_{As}	W_{Pb}	W_{Cu}	W_{Zn}
1	0.034	0.342	0.217	0.112	0.150	0.146
2	0.099	0.105	0.389	0.086	0.151	0.170
3	0.033	0.305	0.268	0.099	0.155	0.140
4	0.057	0.208	0.210	0.140	0.166	0.221
5	0.044	0.297	0.219	0.106	0.135	0.199

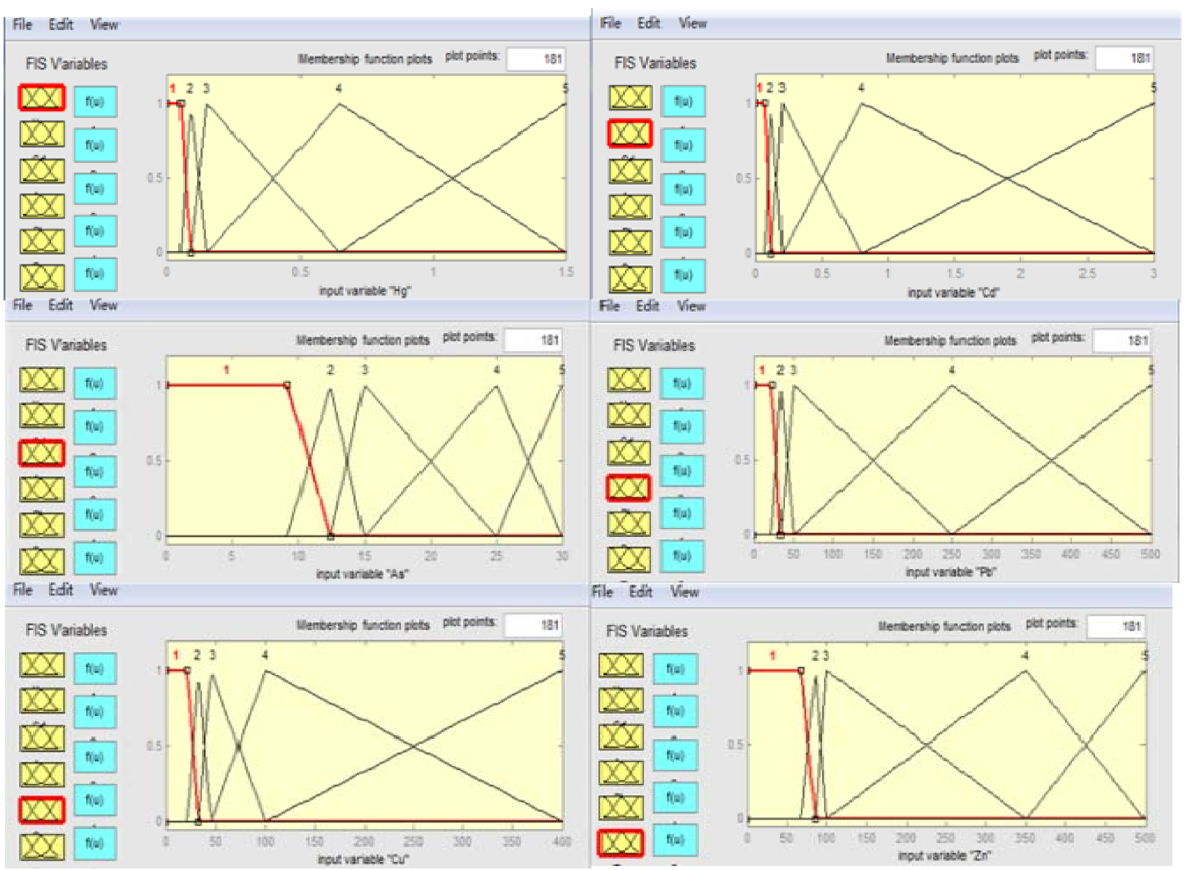

Fig. 1: Membership functions of six heavy metal element

According to Table 7, the weight of five sampling points are calculated through formula (5). The results are shown in Table 8.

According to the grading standard, using MATLAB-FIS membership function editor to generate the corresponding membership function. In this study, we use the semi trapezoidal function and linear trigonometric function to generate the membership functions. The results are shown in Fig. 1.

Finally, we take sample point 1 as an example, the fuzzy relational matrix is obtained:

$$R = \begin{bmatrix} 0.4167 & 0.5833 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.8191 & 0.1910 \\ 0 & 0 & 0.81 & 0.19 & 0 \\ 0 & 0 & 0.8528 & 0.156 & 0 \\ 0 & 0 & 0.4182 & 0.5636 & 0 \\ 0 & 0 & 0.856 & 0.144 & 0 \end{bmatrix} \tag{6}$$

The weight sets of various metal contaminants of the sample point 1 has been shown in Table 8. We can get:

$$W = \{W_1\ W_2\ W_3\ W_4\ W_5\ W_6\} \\ = \{0.0343\ 0.3421\ 0.2169\ 0.1115\ 0.1497\ 0.1455\} \tag{7}$$

In this way, the fuzzy comprehensive evaluation vector of sample point 1 is:

$$B_1 = W \times R \\ = \{0.0143\ \ 0.02\ \ 0.4579\ \ 0.4408\ \ 0.0653\} \tag{8}$$

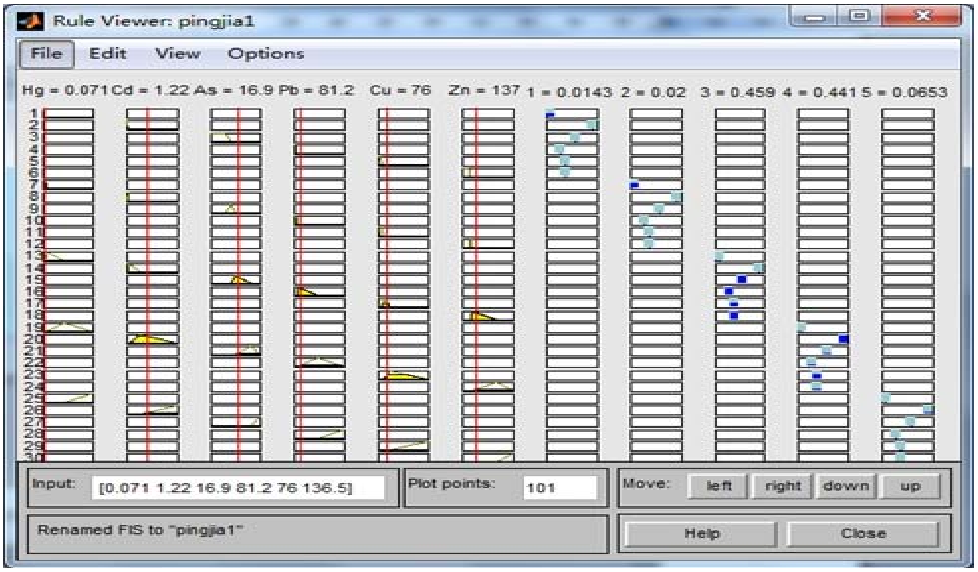

Fig. 2: Rule observer for sampling point 1

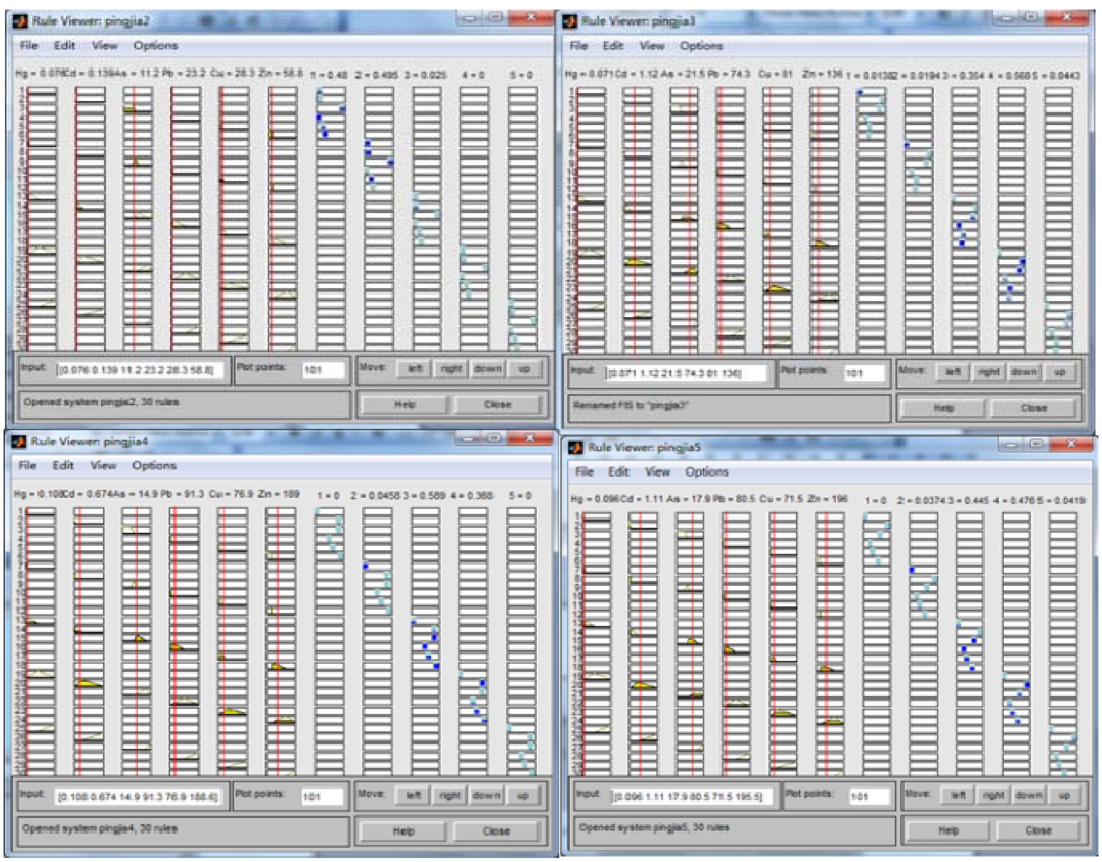

Fig. 3: Rule observers for sampling point 2-4

The evaluation results obtained by MATLAB simulation are shown in Fig. 2.

It can be seen in Fig. 2, the sampling point one's comprehensive evaluation vector is $B_1 = \{b_1 b_2 b_3 b_4 b_5\} = \{0.0143\ \ 0.02\ \ 0.459\ \ 0.4415\ \ 0.0653\}$. The results are consistent with the results of the comprehensive evaluation, which prove that the simulation results are reliable (Wang and Shijun, 2006).

Among them, $b_3>b_4>b_5>b_2>b_1$, According to the principle of maximum membership degree, the comprehensive evaluation of soil sampling point 1 is level 3, which is light pollution. Figure 2 longitudinal dark part followed by Hg, CD, as, Hg, Pb, Cu, Zn ,totally six kinds of heavy metal elements at all levels of the corresponding membership, which 1~6 said level 1 membership degree, 7 to 12 said level 2 membership degree and 13~18 said level 3 membership degree, 19 to 24 said level 4 membership degree, 25~30 said level 5 membership degree (Yan and Yi, 2003).

In the same way, the comprehensive evaluation vector of the sampling points 2-5 are:

$$\begin{cases} B = \{b_1\ b_2\ b_3\ b_4\ b_5\} \\ \quad = \{0.48\ \ 0.495\ \ 0.025\ \ 0\ 0\} \\ B = \{b_1\ b_2\ b_3\ b_4\ b_5\} \\ \quad = \{0.0138\ \ 0.0194\ \ 0.354\ \ 0.568\ \ 0.0443\} \\ B = \{b_1\ b_2\ b_3\ b_4\ b_5\} \\ \quad = \{0\ 0.0458\ \ 0.589\ \ 0.368\ \ 0\} \\ B = \{b_1\ b_2\ b_3\ b_4\ b_5\} \\ \quad = \{0\ 0.0374\ \ 0.445\ \ 0.476\ \ 0.0419\} \end{cases} \tag{9}$$

The simulation results in MATLAB are shown in Fig. 3. The results show that the sampling point 2 is still clean, the sampling point 3 is pollution, the sampling point 4 is light pollution and the sampling point 5 is pollution.

CONCLUSION

Nemerow index method has highlighted the impact of the largest pollution on environmental quality. This way avoid the phenomenon of average value weaken metal pollution weight element occurred. However, it is too high to highlight the impact of the largest pollution index of pollutants on the environment, so that the evaluation of environmental quality is not enough. But its calculation is small, the method is simple to understand, so it is widely recognized. The fuzzy comprehensive evaluation method, which can be seen in the results of the evaluation, can reflect the actual soil pollution risk in the study area. In a certain extent can effectively overcome the phenomenon of evaluation results inaccurate caused by abnormality of a certain or some heavy metals pollution. Meanwhile, it can reduce the phenomenon of evaluation results does not conform to the actual caused by measurement error. Therefore, this method can be used as an effective method to evaluate the pollution degree of heavy metals in the soil. In this study, we use Matlab-fis toolbox to simplify large amount of calculation and the accuracy is greatly improved, but when this method in the face of a large number of data, computing was still very tedious. At the same time, the model has not yet been fixed and don't have an unified standard, this need in-depth study.

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