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The establishment and application of fuzzy comprehensive model with weight based on entropy technology for air quality assessment

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Abstract

Based on analyzing the interconnection and dynamics of poverty of city air system, assessment elements and theirs uncertainty were identified. Then assessment criterion of city air quality factors was formulated by established descending half of trapezium function. Factors' weight was computed according to entropy technology which was put forward as an innovation in this paper. Because entropy technology was good at making using of adequate information and degree of order inner the initial factors' monitoring values. Fuzzy comprehensive model based on entropy technology for air quality assessment was established by improving the method of computing factors' weights. Finally, the new model was applied to assess air quality of Fuxin city in 2009, which showed that assessment result coincided with objective air quality condition of Fuxin city greatly.

Keywords:air quality assessment;fuzzy comprehensive;weight;entropy technology.

1. Introduction

It is of great significance for having an objective and precise assessment on city air quality and a correct understanding of current status and trends of air pollution and exerting urban air pollution control and the implementation of the sustainable development strategy based on the actual monitoring results [1]. There are many measures for current air quality assessment, such as grey mathematical method whose information utilization and accuracy have been greatly improved but the evaluation of the results have low resolution[2], including grey clustering, neural networks, composite index and so on. Fuzzy mathematics, which is not only can reflect air quality status in different space and time and "contribution rate" of pollutants that the process have no restrict from pollutants, but also taking a full account into the intercommunication and interaction in various factors, is better able to reflect objective things containing ordinary and uncertainty. But for "contribution rate", that is, the methodology for determining appropriate weights or not affect the overall evaluation of the results of right or wrong directly [3]. Therefore, this paper via utilizing entropy to improvement the empowering links of fuzzy comprehensive evaluation model and improve the factor weights in the utilization of original measured information to establish urban air

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quality fuzzy evaluation model based on entropy technology, it has an important practical and theoretical value for both to guide the site evaluation and deepen the theory environmental assessment.

2 Establishment of fuzzy mathematics model with weight

2.1 To establish the set of evaluation factor *U*

According to the fact, select the amount of *n* of some main factor affecting the environmental quality and establish the set of factor of evaluation $U=\{U_1, U_2, \cdots\cdots, U_n\}$[4], giving *m*-discrimination level refer to national standards and establishing an evaluation set $V=\{V_1, V_2, \cdots\cdots, V_m\}$.

2.2 To establish the individual factor for each grade standards of subordinate function y_{ij}

Fuzzy distribution act as lower semi-trapezoid distribution and the sub-threshold is the corresponding environmental quality standards series[5]. Subordinate degree is calculated as follows:

(1) For first-class quality of the environment, *j*=1, its subordinate function is:

$$y_{ij}=\begin{cases} 1 & x_i \le s_{ij} \\ A_{ij}\left(x_i - s_{i(j+1)}\right) & s_{ij} < x_i < s_{i(j+1)} \\ 0 & x_i \ge s_{i(j+1)} \end{cases} \quad (1)$$

x_i —the measured values of the i kinds, mg/L;

s_{ij} — the i factor the j -class standards values of air, mg/L;

$s_{i(j+1)}$ — the i factor and the $(j+1)$ -class standards values of air, mg/L;

A_{ij} — coefficient, obtained by using the median calculation. formula:

$$A_{ij} = \frac{1}{s_{ij} - s_{i(j+i)}} \quad (2)$$

(2)The second level to the $(m-1)$ level of environmental quality, that is $j = 2, 3, \cdots, (m-1)$,when turns $(m-1)$ its subordinate function is:

$$y_{ij}=\begin{cases} 0 & x_i \le s_{i(j-1)} \text{或} x_i \ge s_{i(j+1)} \\ A_{ij}\left(x_i - s_{i(j-1)}\right) & s_{i(j-1)} < x_i < s_{ij} \\ A_{ij}\left(x_i - s_{i(j+1)}\right) & s_{ij} \le x_i \le s_{i(j+1)} \end{cases} \quad (3)$$

$s_{i(j-1)}$ — the first factor and the $(j-1)$ level of environmental quality standard values, mg/L:

A_{ij} A_{ij} —coefficient, is calculated as follows:

$$A_{ij} = \frac{1}{s_{ij} - s_{i(j-1)}} \quad (4)$$

$$A_{ij} = \frac{1}{s_{ij} - s_{i(j+1)}} \quad (5)$$

(3)The last-class environmental quality, that is *j*=*m*, its subordinate function is:

$$y_{ij}=\begin{cases} 1 & x_i \geq s_{i(j-1)} \\ A_{ij}\left(x_i - s_{i(j-1)}\right) & s_{i(j-1)} < x_i < s_{ij} \\ 0 & x_i \leq s_{ij} \end{cases} \quad (6)$$

A_{ij} — Coefficient, is calculated as follows：

$$A_{ij} = \frac{1}{s_{ij} - s_{i(j-1)}} \quad (7)$$

2.3 Establishing fuzzy relationship between evaluation factor and its level

Take U as the set of evaluation factor and v as the set of air mass grade and take data into the specific subordinate function, so we can calculate the fuzzy matrix R as follows:

$$R = \begin{bmatrix} y_{11} & y_{22} & y_{33} \\ y_{21} & y_{23} & y_{24} \\ y_{31} & y_{32} & y_{33} \\ y_{41} & y_{42} & y_{43} \end{bmatrix} \quad (8)$$

2.4The establishment of weight

Entropy weighting, a method, which is made up of the monitoring values of evaluation index in objective conditions, can determine the target and the degree of order and effectiveness by referring to evaluation of information entropy [6]. Because of avoiding the subjectivity of the weights of various factors, and therefore the results of evaluation can be better able to reflect the actual situation.

(1)Assuming that there are m evaluation objects, each object being evaluated has n evaluating indicator, constructing comparison matrix:

$$R = \left(r_{ij}\right)_{m\times n} \quad (i=1,\ 2,\ \cdots,\ m;\ j=1,\ 2,\ \cdots n;\ ) \quad (9)$$

(2)The proportion of i-index value objects below j-indicators is:

$$P_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \ (j=1,\ 2,\ \cdots,\ n) \quad (10)$$

(3)According to the conception of entropy, we can define m-evaluation things and n-evaluation index as:

$$H_i = \frac{-\left(\sum_{i=1}^{m} P_{ij} \ln P_{ij}\right)}{\ln m} \quad (i=1, 2, \cdots, m;\ j=1, 2, \cdots, n) \quad (11)$$

In order to make $\ln P_{ij}$ meaningful, we must assume $P_{ij}=0$, $P_{ij}\ln P_{ij}=0$.

(4)Calculating the entropy of evaluation index:

$$w_i = \frac{1 - H_i}{n - \sum_{i=1}^{n} H_i} \quad (i=1, 2, \cdots, m) \quad (12)$$

So we can conclude the weight.

(5) Composing comprehensive evaluation model B

$$B = \{b_1,\ b_2,\ \ldots,\ b_n\} = A \bullet R \quad (13)$$

3 Fuzzy comprehensive evaluations in application of atmospheric evaluation

3.1 Data sources

We have used fuzzy mathematical model improved to evaluate the air quality in Fuxin in 2009.The data was got from the Fuxin Environmental Protection Department [7].

Table. 1 Daily statistics of main pollutants in 2009 (mg/m^3)

category	PM_{10}	SO_2	NO_2	CO
Industrial zone	0.223	0.051	0.025	1.1
Residential zone	0.220	0.050	0.022	1.2
Traffic zone	0.285	0.083	0.032	1.3
Sanitary zone	0.228	0.040	0.025	1.0

3.2 Determine the evaluation criteria

The air quality assessment in Fuxin which adopted No.2 standard concentration limits from （GB3095-1996） [8]as the assessment basement was carried out.And the national environmental criterion such as Table 2.

Table. 2 Standard concentration of emission of atmospheric pollutants in Fuxin city

Pollution factor	Ⅰ	Ⅱ	Ⅲ
PM_{10}	0.05	0.15	0.25
SO_2	0.05	0.15	0.25
NO_2	0.08	0.08	0.12
CO	4.00	4.00	6.00

3.3 Determination of evaluation space, the evaluation set, and evaluation set indeed, legislative subordinate functions and fuzzy matrix

According to Fuxin city, the actual monitoring data form monitoring station can be used to establish an evaluation set U= $\{u_1, u_2, u_3, u_4\}$ [9] , which were PM_{10}、SO_2、NO_2、CO. According to table 2, evaluation set V={Ⅰ, Ⅱ, Ⅲ} was built. For the Fuxin industrial zone:

1) To establish a set, according to 1:

$$U = \{0.223,\quad 0.051,\quad 0.025,\quad 1.1\}$$

2) To take numerical index in set U into subordinate, this is related to factor so that we can conclude single-factor evaluation matrix:

$$R_1 = \begin{bmatrix} 0 & 0.27 & 0.73 \\ 0.99 & 0.01 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 0 \end{bmatrix}$$

3) Determine the weight set:

①build the comparison set based on the data in table 1:

$$R = \begin{bmatrix} 0.223 & 0.051 & 0.025 & 1.1 \\ 0.220 & 0.050 & 0.022 & 1.2 \\ 0.228 & 0.083 & 0.025 & 1.0 \\ 0.228 & 0.040 & 0.025 & 1.0 \end{bmatrix}$$

②According to the formula (9) to (12) to calculate the weight set of each index:

$$A = \begin{pmatrix} 0.657 & 0.100 & 0.161 & 0.082 \end{pmatrix}$$

The fuzzy comprehensive evaluation could be concluded:

$$B = A \bullet R = \begin{pmatrix} 0.657 & 0.100 & 0.161 & 0.082 \end{pmatrix} \begin{bmatrix} 0 & 0.27 & 0.73 \\ 0.99 & 0.01 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 0 \end{bmatrix}$$

4) We have achieved a subset of fuzzy evaluation of air quality in Fuxin industrial zone in 2009:

$$B = (0.342 \quad 0.421 \quad 0.480)$$

The step, which is firstly find the single-factor evaluation matrix and secondly find the fuzzy subset of the weighting coefficient, at last, using comprehensive evaluation fuzzy subset B to have an identification of pollution levels of each functions, is the same as the ways that air quality assessment. The fuzzy matrix derived from the subordinate function from the residential area, traffic area and dear area.

$$R_2 = \begin{bmatrix} 0 & 0.3 & 0.7 \\ 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 0 \end{bmatrix} \quad R_3 = \begin{bmatrix} 0 & 0 & 1 \\ 0.67 & 0.33 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 0 \end{bmatrix} \quad R_4 = \begin{bmatrix} 0 & 0.22 & 0.78 \\ 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 0 \end{bmatrix}$$

The subset of the evaluation of the three functional areas after normalized:

$$B_2 = (0.343 \quad 0.440 \quad 0.460) \quad B_3 = (0.31 \quad 0.276 \quad 0.675) \; B_4 = (0.343 \quad 0.392 \quad 0.512)$$

3.4 Assessment results

In order to facilitate analysis, we will take advantage of the results of air environmental quality in Fuxin which is improved by the model of fuzzy division to compare with that applied to Shanghai Air Quality Index (composite index) [10] provided by Fuxin Environmental Protection Department of the same year, Table 3.

Table.3 Results of air quality got from Fuzzy Synthetic Evaluation in different functional area of Fuxin city in 2009

evaluation unit	comprehension index	Evaluation results	
		$\{b_j\}_{max}$	level
Industrial park	1.43	0.480	Ⅲ
Residential park	1.41	0.460	Ⅲ
Traffic zone	1.88	0.675	Ⅲ
Dear area	1.41	0.512	Ⅲ

We can see from Table 3, the results of evaluating the air environment in the same year are almost the same by improved fuzzy model and Shanghai Index method. Fuzzy comprehensive evaluation results of grade Ⅲ are derived from entropy method and the main pollutant is air particulate matter that is in line with the actual situation in Fuxin. There are too many small size heating facilities in winter. We find that comprehension index is not obvious for the effects of the classification of similar data for making off; however, the fuzzy comprehensive evaluation model with weight is ideal for evaluating criteria blurring the boundary. In 2009, the air condition in Fuxin is on a smaller degree of membership of clean and in a lager degree of membership of light and moderate pollution, so it is essentially a moderate pollution mainly due to SO_2、CO、NO_2 pollution is relatively young and PM_{10} pollution is heavy. Therefore, the main factors affecting air quality is the concentration of PM_{10}. If we can control the PM_{10} particulate matters, the air in Fuxin will be maintained in a clean level.

4 Conclusions

（1）Air environment evaluation in Fuxin result of fuzzy comprehensive evaluation model with weight based on entropy technology shows that the air quality belong to Ⅲ.And PM_{10} is main pollutant which pollution contribution rate is highest.

（2）We can make the entropy theory of information to be introduced into the calculation of air quality assessment to calculate weight that reflects the utility value of disorder, so as to reduce the impact of subjective factors effectively. The fuzzy comprehensive evaluation not only can express ambient air quality reaching the level, but also compare the air quality for the different measuring points. It can also resolve the real sample quality classification attribution when measured values close to the evaluation criteria on both sides of the border.

（3）To introduce entropy weight fuzzy comprehensive evaluation model and improve the evaluation methods, we take both the fuzzy phenomenon of environment and various factors of related things into account. The overall merit can better reflect the air quality of a certain region comprehensively and objectively, so the results are more in line with the actual situation.

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References

[1]Weidong Yang. The Research Of Fuzzy Mathematics Model On The Atmosphere Environmental Quality Of Wuhan City:*[D] master thesis of the Wuhan University of Technology.*2002.
[2]Shujia Yang,Siping Wang,Xinqi Zheng. Method Of Entropic Coefficients For Distribute Basic Farmland Guideline*[J]. Resource Development & Market* 2006;22(4):305-314.
[3]Qiansheng Mu. Attribute Recognition Theoretical Model With Application[J]. University Pekingnsis(Scientiarum Naturalium) 1999;33(1):12-20.
[4]Xiaoliang Zhao,Ziling Song,Junshan Hu, Foundation And Application Of Varying Weight Identify Model Of Mine Water Quality Evaluation*[J]. Open Mining Technology* 2005;2(1):32-34.
[5]Xiaoliang Zhao,Ziling Song,Yang Zhou,Guozhi Zhao. Assessment Approach To Coalmine Safety Based On Continental Distance Model With Varying Weight*[J].Journal Of Safety And Environment* 2005;5(5):9-11.
[6]Bing He,Denghao Gao. Variable Weight Recognition Model Of Atmospheric Quality Comprehensive Assessment And Its Application*[J]. Environmental Engineering* 2001;(6):57-58..
[7]Jixian Xiao. Assessment Of Fuzzy Comprehensive Evaluation's Application In Evaluation of atmospheric environment's quality. Environmental engineering 1994;(6):46-49.
[8]Guofang Zhang,Fanbiao Bao, Research On Logistics Centre With Fuzzy Synthesis Evaluation Of Entropy Weights Model*[J].Journal Of Wuhan University Of Technology* 2005;27(7):23-26.
[9] Xiaoliang Zhao,Ziling Song. Research of Air Quality Assessment Model Based On Continental Distance Model With Varying Weight *[J].Journal of LiaoNing Technical Unversity* 2005;34(5):30-33.
[10]Renchen Hai,Wanben Tai. Several Features Of Current Air Quality In China*[J].Environment Science Research* 2004;17(1):1-6.