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Empirical Analysis on MSW Optimization Management Technology based on Fuzzy Method

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Abstract: The scientific disposal of Municipal Solid Waste (MSW) is of great significance to the urban ecological environment and the residents' health. Taking into account the economic, technical, environmental, social indicators, as well as their subindicators, analyzing fourteen evaluation factors, the paper discusses four kinds of disposal methods of MSW using AHP and Fuzzy comprehensive evaluation. The results indicate that the most suitable waste disposal method is the comprehensive disposal method.

Keywords: AHP, fuzzy comprehensive evaluation, index system.

1. INTRODUCTION

In recent years, with rapid development of economy and continuous improvements in living standards, the output of municipal solid waste (MSW) is on the increase. Some cities are faced with the issue of being besieged with MSW, which has brought serious harm to the people's health.

The effective methods of solving MSW problem involves volume and weight reduction, harmless treatment such as reutilization and recycle, power-converting. At present, MSW disposal technology involves landfill, compost and incineration. The traditional sanitary landfill requires a lot of land offer, therefore MSW treatment should be diversified and varied according to local environment and economic level [1, 2].

Taking Shunyi waste disposal plant located in the suburbs of Beijing (a megalopolis) as research object, this paper establishes comprehensive evaluation index system of MSW disposal. Four kinds of MSW disposal technologies, that is, landfill, compost, incineration, and comprehensive treatment are analyzed by AHP and fuzzy comprehensive evaluation method.

2. THE ESTABLISHMENT OF INDEX SYSTEM OF MSW DISPOSAL TECHNOLOGY

A scientific and systematic overall evaluation of index system is the foundation of comprehensive evaluation. This paper selects economic, technological, environmental and social indicators as four first-level indexes, set up several second-level indicators below each first-level indexes, and constructed a comprehensive evaluation index system of MSW disposal method (Table **1**) [3-5].

2.1. Determination of Index Weights by AHP Method

The judgment matrix is given on the basis of some institutions and experts on MSW disposal technology consulting. The first-level and the second-level weights are calculated by AHP. Table **2** indicates the process of four B layers of index weight calculation. ω_i is the weight coefficient, $\lambda_{\max}$ is the largest eigen value of the judgment matrix, RI is random consistency index. When $CR < 0.1$, the judgment matrix has consistent satisfactory values.

Similarly, the second-level weights are obtained as follows: (in Table **3**).

2.2. The Selection of Membership Function

Different membership degree functions are given for all second-level indexes. Here the total project investment (a second-level index) is taken as a demonstration. Due to the difference of technological level, the average investment date of three MSW disposal method (sanitary, landfill, compost, incineration) are not precise, so the experience data are adopted. The average investment of landfill is about 600-1500 million /100 tons; the average investment of compost is about 500-4000 million /100 tons; the average investment of incineration technology is about 3500-6500 million /100 tons; the average investment of comprehensive treatment is about 1500-3000 million /100 tons. Due to the large differences of four MSW disposal method investment amounts, different membership degree functions are given corresponding to four MSW disposal methods (Table **4**) [6, 7]. The evaluation set is given, $U_{11} = (H, G, M, L)$ that is, (higher investment amount, high investment amount, middle investment amount, low investment amount). The establishment of the membership function are four kinds of treatment technology on the U_{11}.

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Table 1. Index system of MSW disposal technology.

Target Layer	The First Level	The Second Level
Index system	Economic indicator	The project total investment
		The unit operation cost
		The profit rate of investment
		Land occupation
	Technical indicator	Technology reliability
		Siting requirements
		The processing object requirement
		The operation and management requirement
	Environmental indicator	Environment pollution
		Secondary pollution
		Health and safety evaluation
	Social indicator	Literacy of public
		Public participation level
		Laws and regulations

Table 2. Calculation results of judgment matrix A-B layer.

A	$B1$	$B2$	$B3$	$B4$	ω_i	$\lambda_{\max}$	Consistency check
$B1$	1	3	1/5	1/2	0.1428		$RI = 0.90$
$B2$	1/3	1	1/5	1/3	0.0747	4.1314	$CI = (\lambda_{\max} - n)/(n-1) = 0.0438$
$B3$	5	5	1	3	0.5602		$CR = CI/RI = 0.0487 < 0.1$
$B4$	2	3	1/3	1	0.2223		

Table 3. Calculation results of judgment matrix.

Judgment Factors	CR	Weight Coefficient
$U = \{B1, B2, B3, B4\}$	0.0487	$A = (0.1428, 0.0747, 0.5602, 0.2223)$
$U1 = \{C1, C2, C3, C4\}$	0.0039	$A1 = (0.42, 0.23, 0.23, 0.12)$
$U2 = \{C5, C6, C7, C8\}$	0.0054	$A2 = (0.27, 0.48, 0.09, 0.16)$
$U3 = \{C9, C10, C11\}$	0.0738	$A3 = (0.1007, 0.2255, 0.6738)$
$U4 = \{C12, C13, C14\}$	0.0553	$A4 = (0.2524, 0.4158, 0.3318)$

$$f_H(x_1) = \begin{cases} 1, x \ge a_1 \\ (x - a_2)/(a_1 - a_2), a_2 < x < a_1 \\ 0, x \le a_2 \end{cases}$$

$$f_G(x_1) = \begin{cases} (a_3 - x)/(a_3 - a_4), a_4 < x < a_3 \\ 1, a_5 \le x \le a_4 \\ (x - a_6)/(a_5 - a_6), a_6 < x < a_5 \end{cases}$$

$$f_M(x_1) = \begin{cases} (a_8 - x)/(a_7 - a_8), a_8 < x < a_7 \\ 1, a_9 \le x \le a_8 \\ (x - a_{10})/(a_9 - a_{10}), a_{10} \le x < a_9 \end{cases}$$

$$f_L(x_1) = \begin{cases} 0, x > a_{11} \\ (a_{11} - x)/(a_{11} - a_{12}), a_{12} \le x \le a_{11} \\ 1, x < a_{12} \end{cases}$$

Table 4. Comparison table of four disposal methods.

Comparison of Content	Sanitary Landfill	Hot Composts	Burn	Comprehensive Treatment
Unit investment(million/t)	0.06-0.15	0.05-0.4	0.35-0.65	0.15-0.3
Operation cost(yuan/t)	50-80	50-110	Around 150	Around 85
Land occupancy	large	more	less	less
Exhaust gas	Produce methane	Acid gas emissions	Produce harmful gases	Heavy metal
Waste water	Landfill leachate	Less waste leachate	The possibility is very small	The possibility is small
soil	Leachate pollution	Soil compaction	Settlement of gaseous pollutants	
Applicable condition	All kinds of life garbage	Perishable goods accounted for 40%	Calorific value greater than 4127KJ/kg	All kinds of life garbage
Technology reliability	reliable	More reliable	More reliable	More reliable
Safety of operation	Good, but pay attention to gas explosion	better	better	better
Management level	The general requirements	Higher requirements	High requirements	High requirements
Literacy of public	The general requirements	Higher requirements	High requirements	High requirements
Public participation level	poor	better	good	good
Laws and regulations	No reduction	20%	More than 80%	More than 90%

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Normal membership function model is described as follows:

$$f_H(x)=\exp[-(\tfrac{x-b_1}{\sigma})^2],\ f_G(x)=\exp[-(\tfrac{x-b_2}{\sigma})^2,$$

$$f_M(x)=\exp[-(\tfrac{x-b_3}{\sigma})^2],\ f_L(x)=\exp[-(\tfrac{x-b_4}{\sigma})^2]$$

The evaluation set is (excellent, good, medium, poor), and the corresponding score for (4, 3, 2, 1), membership is as follows:

Excellent: $f(x)=\begin{cases}1, x\geq 1.5\\(x-1.2)/0.3, 1.2<x<1.5\\0, x\leq 1.2\end{cases}$,

good: $f(x)=\begin{cases}1, x\geq 1.2\\(x-0.9)/0.3, 0.9<x<1.2\\0, x\leq 0.9\end{cases}$

medium: $f(x)=\begin{cases}1, x\geq 0.9\\(x-0.6)/0.3, 0.6<x<0.9\\0, x\leq 0.6\end{cases}$,

poor: $f(x)=\begin{cases}1, x\geq 0.6\\(x-0.3)/0.3, 0.3<x<0.6\\0, x\leq 0.3\end{cases}$

3. FUZZY COMPREHENSIVE EVALUATION PROCESS

We calculate each index membership degree for four classes, two class membership matrix is obtained (Table **5**) (including total engineering investment and unit operating costs as low as possible, therefore the calculation results are in reverse order.)

The calculation of the judgement matrix

According to the fuzzy evaluation results and the weight coefficient, as indicated in the table, the first two grade evaluation matrix are calculated from the bottom to the top and compute a level judgment matrix

$$M_{1L}=A1\circ R_{1L}=\begin{pmatrix}0.42 & 0.23 & 0.23 & 0.12\end{pmatrix}\circ$$

$$\begin{pmatrix}0 & 0.39 & 0 & 0\\1 & 0 & 0 & 0\\0 & 0 & 0 & 0.183\\0.9 & 0.3 & 0.6 & 0.2\end{pmatrix}=\begin{pmatrix}0.34 & 0.2 & 0.07 & 0.066\end{pmatrix}$$

Similarly

$$M_{1C}=\begin{pmatrix}0.072, & 0.3534, & 0.266, & 0.012\end{pmatrix}$$

$$M_{1B}=\begin{pmatrix}0.245, & 0.198, & 0.372, & 0.006\end{pmatrix},$$

$$M_{1S}=\begin{pmatrix}0.246, & 0.187, & 0.112, & 0.021\end{pmatrix},$$

$$M_{2L}=\begin{pmatrix}0.0135, & 0.233, & 0.287, & 0.48\end{pmatrix},$$

Table 5. The calculation results of fuzzy comprehensive evaluation.

Evaluation Object	Membership Function	The Evaluation Matrix			
		Sanitary Landfill	Composts	Burn	Comprehensive Treatment
The project total investment	I	(0,0.39,0,0)	(0,0.67,0,0)	(0,0,0.6,0)	(0,0.3,0.1,0)
The unit operation cost	I	(1,0,0,0)	(0,0,1,0)	(0,0,0.46,0)	(0,0.21,0,0)
The profit rate of investment	II	(0,0,0,0.183)	(0,0,0,0.001)	(0.7,0.6,0.01,0)	(0.6,0.03,0.3,0.07)
Land occupation	II	(0.9,0.3,0.6,0.2)	(0.6,0.6,0.3,0.1)	(0.7,0.5,0.1,0.05)	(0.9,0.05,0.01,0.04)
Technology reliability	III	(0.05,0.5,0.5,0)	(0,0.07,0.9,0)	(0,0.07,0.9,0)	(0,0.9,0.1,0)
Siting requirements	III	(0,0,0,1)	(0,0,1,0)	(0.3,0.3,0.3,0)	(0.4,0.4,0.2,0)
The processing object requirement	III	(0,0.2,0.8,0)	(0,0,0,1)	(0,0.3,0.7,0)	(0,0.9,0.1,0)
The operation and management requirement	III	(0,0.5,0.5,0)	(0,0.3,0.7,0)	(0,0,1,0)	(0.2,0.4,0.4,0)
Environment pollution	III	(0,0,1,0)	(0,0.03,0.97,0)	(0.1,0.4,0.5,0)	(0,0.5,0.5,0)
Secondary pollution	III	(0,0,1,0)	(0,0.2,0.8,0)	(0,0.5,0.5,0)	(0,0.6,0.4,0)
Health and safety evaluation	III	(0,0,0,1)	(0,0,1,0)	(0.3,0.3,0.4,0)	(0.1,0.5,0.4,0)
Literacy of public	III	(0,0,0,1)	(0,0,1,0)	(0.2,0.4,0.3,0.1)	(0.4,0.3,0.2,0.1)
Public participation level	III	(0,0,0,1)	(0,0,1,0)	(0.2,0.4,0.4,0)	(0.4,0.3,0.3,0)
Laws and regulations	III	(0.2,0.4,0.4,0)	(0,0.2,0.8,0)	(0,0,1,0)	(0,0.8,0.2,0)

$M_{2C} = (0,\quad 0.067,\quad 0.835,\quad 0.09)$,
$M_{2B} = (0.144,\quad 0.19,\quad 0.61\quad 0)$,

$M_{2S} = (0.224,\quad 0.580,\quad 0.196,\quad 0)$,
$M_{3L} = (0,\quad 0,\quad 0.3262\quad 0.6738)$,

$M_{3C} = (0,\quad 0.048,\quad 0.9519,\quad 0)$,
$M_{3B} = (0.2122,\quad 0.3653,\quad 0.2700,\quad 0)$,

$M_{3S} = (0.0674,\quad 0.4266\quad 0.4100,\quad 0)$,
$M_{4L} = (0.066,\quad 0.133,\quad 0.133,\quad 0.668)$

$M_{4C} = (0,\quad 0.066,\quad 0.266,\quad 0)$,
$M_{4B} = (0.134,\quad 0.267,\quad 0.574,\quad 0.025)$,

$M_{4S} = (0.267,\quad 0.466,\quad 0.441,\quad 0.025)$.

Then the two level evaluation matrix is formed as follows:

$$M_L = \begin{pmatrix} M_{1L} \\ M_{2L} \\ M_{3L} \\ M_{4L} \end{pmatrix} = \begin{pmatrix} 0.34 & 0.2 & 0.07 & 0.066 \\ 0.0135 & 0.233 & 0.287 & 0.480 \\ 0 & 0 & 0.3262 & 0.6738 \\ 0.066 & 0.133 & 0.133 & 0.668 \end{pmatrix}$$

Similarly,

$$M_C = \begin{pmatrix} M_{1C} \\ M_{2C} \\ M_{3C} \\ M_{4C} \end{pmatrix},\ M_B = \begin{pmatrix} M_{1B} \\ M_{2B} \\ M_{3B} \\ M_{4B} \end{pmatrix},\ M_S = \begin{pmatrix} M_{1S} \\ M_{2S} \\ M_{3S} \\ M_{4S} \end{pmatrix}$$

Then according to the weight of index economy, technology, environment, and society

$A = (0.1428,\quad 0.0747,\quad 0.5602,\quad 0.2223)$

Overall evaluation results can be obtained as $G = A \circ M$

$G_L = (0.064,\quad 0.076,\quad 0.244\quad 0.571)$,
$G_C = (0.010,\quad 0.097,\quad 0.693,\quad 0.008)$

$G_B = (0.194,\quad 0.306,\quad 0.378,\quad 0.006)$
$G_S = (0.149,\quad 0.413,\quad 0.389,\quad 0.008)$

This still does not depict the advantages of four methods, take on the four levels of quantitative score

$D = (4,\quad 3,\quad 2,\quad 1)^T$

$T = G \circ D$, we can get

$T_L = G_L \circ D = 1.543$, $T_C = G_C \circ D = 1.725$,

$$T_B = G_B \circ D = 2.456, \; T_S = G_S \circ D = 2.621$$

From the above results, we can see that, the integrated treatment has the highest scores and is most suitable comprehensive treatment method for Shunyi garbage disposal plant construction.

4. CONCLUSION

This paper takes waste treatment plant as research object and arrives at the conclusion that the most suitable treatment method for the plant is comprehensive waste disposal method. Comprehensive waste disposal method has all the advantages of landfill, compost, incineration, thus has become general trend of waste disposal worldwide.

CONFLICT OF INTEREST

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

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