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Lanzhou Municipal Solid Waste Sanitary Landfill Site Selection Study

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Abstract

To address the problem of strong subjectivity and lack of objectivity and scientificity in the selection of municipal solid waste sanitary landfill site in Lanzhou City, the optimal site for the construction of municipal solid waste sanitary landfill in Lanzhou City was studied by using analytic hierarchy process and considering the influence of four factors on the selection of municipal solid waste sanitary landfill site, including construction cost, collection and transportation distance, environmental protection and site topography. The results show that in the evaluation system of municipal solid waste sanitary landfill site selection, the weights of the factors in the criterion layer on the decision objectives are environmental protection (0.5791) > construction cost (0.2326) > site topography (0.1213) > collection and transportation distance (0.0670); the weights of the factors in the scheme layer on the decision objectives are Huangyu town (0.4928) > Yaojie town (0.3069) > Agan town (0.2004). The results of the study provide technical and theoretical references for the site selection of municipal solid waste sanitary landfill in Lanzhou City.

Keywords

Lanzhou City; Analytic Hierarchy Process; Landfill Site Selection; Weights.

1. Introduction

In recent years, with the development of social economy, the acceleration of urbanization, the increase of urban population and the improvement of people's living standard, the types and quantities of urban waste have also increased. According to the statistics of National Bureau of Statistics[1], in 2010, China's domestic waste removal volume was 158.05 million tons, and ten years later in 2019, China's domestic waste removal volume grew to 242.06 million tons. The amount of domestic waste removed in Gansu Province grew from 2.7825 million tons to 2.7971 million tons in ten years, and in 2018, the amount of domestic waste removed in Gansu Province even reached 2.8119 million tons, and the average amount of domestic waste harmlessly treated reached 10,244 tons per day in this year. The increasing amount of domestic waste generation poses a huge challenge for China's urban management and environmental governance: affecting hygiene, spreading diseases[2]; nowhere to pile up, garbage surrounding the city[3]; generating ooze, polluting water[4-7]; polluting the atmosphere, causing explosions[8]; not easy to disintegrate, white pollution[9]. As American futurist Alvin Toffler said in "The Third Wave": "Following the agricultural revolution, industrial revolution, and information revolution, another revolution affecting human survival and development will be the garbage revolution at the turn of the century". The rational disposal of domestic waste has become a problem that all human beings have to face, and how to realize the reduction, degree of resourceization and harmlessness of domestic waste is a problem that China and even all countries in the world need to solve. At present, the treatment methods of domestic waste in China mainly include

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landfill, incineration and composting. In foreign countries, incineration method is widely used, some developed countries with small land area such as Japan, Denmark, Switzerland, etc., incineration has become the main means of domestic waste treatment, while countries with large land area such as China, the United States, the United Kingdom, etc. are mainly sanitary landfill. Sanitary landfill is the most economical and safest way to dispose of municipal waste, with the advantages of mature technology, simple operation, low operation cost and wide application. According to the statistics of the National Bureau of Statistics[1], the sanitary landfill of domestic waste in 2019 was 109.48 million tons of harmless disposal, accounting for 45.2% of the total amount of domestic waste removed in that year. During the decade from 2010 to 2019, the sanitary landfill harmless treatment plants of domestic waste in China grew from 498 to 652, the sanitary landfill harmless treatment capacity of domestic waste grew from 0.289957 million tons per day to 0.367013 million tons per day, and the sanitary landfill harmless treatment volume of domestic waste grew from 95.98 million tons to 109.48 million tons. With the increase of municipal solid waste sanitary landfill treatment volume, the site selection and construction of landfill has attracted attention. Site selection is the first stage of landfill construction. The choice of site is the key to the feasibility of landfill construction, the economy of the operation process, and the protection of the surrounding environment, which is of great significance to the sanitary landfill disposal of municipal solid waste. At present, the selection of municipal solid waste sanitary landfill site in Lanzhou City mainly relies on human subjective judgment, although the surrounding environmental conditions, technical maturity and engineering investment and other factors are also taken into account, but lack of science, objectivity and effectiveness. How to select the best site suitable for the construction of Lanzhou municipal solid waste sanitary landfill from many alternative sites scientifically, quickly and efficiently is of great significance to the sanitary landfill treatment of Lanzhou municipal solid waste and the realization of harmless, resourcefulness and reduction of domestic waste treatment.

Scholars at home and abroad have conducted many researches on the site selection of municipal solid waste sanitary landfill using analytic hierarchy process: J. Zhu et al[10] used analytic hierarchy process to study the site selection of sanitary landfill in southeastern Anhui Province. Z.Z. Zhou[11] used analytic hierarchy process to evaluate the suitability of a city landfill site in Guangdong Province, taking into account five major factors: geological environment, environmental protection, transportation, construction conditions and social impact, and finally concluded that the study area was not suitable for construction. Y.B. Zhai et al[12] evaluated the suitability of domestic waste landfill sites in Yongzhou City based on the principle of hierarchical analysis and obtained satisfactory results. T. Chen et al[13] used analytic hierarchy process to analyze specific candidate sites separately, calculated the comprehensive suitability evaluation score of each site, compared the scores of each candidate site, and arrived at the best site; J.J. Huang et al[14] used Wuhan urban geological survey as the basis, based on the basic principles of landfill site selection and the basic characteristics of the environmental impact caused by the landfill site. Based on the basic characteristics of urban geological survey in Wuhan city, the landfill suitability index system was established by using analytic hierarchy process and fuzzy evaluation method, and the best site was determined; Şehnaz Şener et al[15] combined analytic hierarchy process with GIS to consider the influence of hydrogeology, land use and slope on the landfill site selection, and finally determined the best site.

2. Study on the Location of Municipal Solid Waste Sanitary Landfill in Lanzhou

2.1 Research Background

Lanzhou City is located in the northwestern part of China and the central part of Gansu Province, with a temperate continental climate. The city is located in the northwest-southeast river valley, surrounded by mountains on many sides, with high terrain in the west and south and low terrain in the northeast, with a total area of 13192km2, of which the urban area is 1631.6km2, a city with a long history and culture[16]. Now it is proposed to choose a place to build a sanitary landfill for municipal solid waste from three towns in Lanzhou, namely, Agan Town, Qilihe District, Yaojie Town, Honggu District and Huangyu Town, Qilihe District.

2.2 Research Methodology

An evaluation study of municipal solid waste disposal options in Lanzhou City using analytic hierarchy process. Analytic hierarchy process is a multi-objective decision analysis method proposed by T.L. Saaty, an American operations researcher, in the early 1970s. By decomposing the elements related to decision making into levels of objectives, criteria, and options, quantitative and qualitative analysis is conducted to finally determine the decision solution[17].

3. Study on Landfill Site Selection based on Analytic Hierarchy Process

3.1 Building Structural Model

The evaluation analysis model was constructed by taking Agan town, Yaojie town and Huangyu town as the scheme layer, four factors of construction cost, collection and transportation distance, environmental protection and site topography as the criterion layer, and the best site for municipal solid waste sanitary landfill as the target layer to study the best site applicable to the construction of municipal solid waste sanitary landfill in Lanzhou city, and the model is shown in Figure 1.

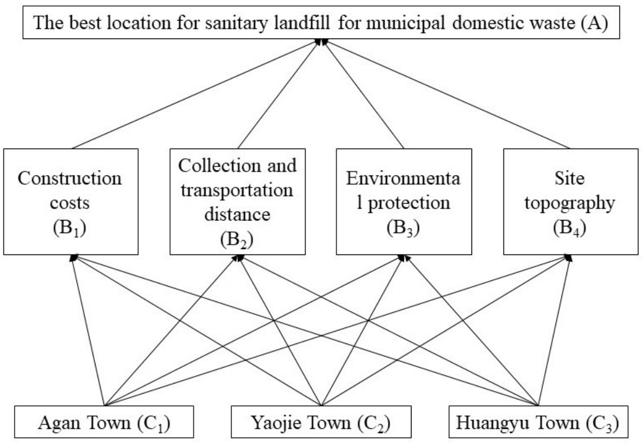

Figure 1. Model diagram of municipal solid waste sanitary landfill site selection.

3.2 Constructing the Judgment Matrix

Each criterion in the criterion layer does not necessarily have the same weight in the objective measure, and each of them has a certain proportion in the mind of the decision expert. The numbers 1 to 9 and their reciprocals are cited as scales to define the judgment matrix A = (aij)n×n. The judgment matrix scales are defined as shown in Table 1.

Table 1. Definition of judgment matrix scales

Scale	Definition
1	Factor i is as important as factor j
3	Factor i is slightly more important than factor j
5	Factor i is significantly more important than factor j
7	Factor i is very important than factor j
9	Factor i is heavily important than factor j
2, 4, 6, 8	Denotes the middle value of the above adjacent judgments
Countdown	Factor j is critical relative to factor i

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3.3 Consistency Test

(1) Calculation of consistency index *CI*

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{1}$$

Where λmax is the maximum eigenvalue of the judgment matrix.

(2) Find consistency indicators *RI* (see Table 2)

Table 2. Average random consistency index

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RI	0	0	0.52	0.89	1.12	1.24	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58

(3) Calculate the consistency ratio *CR*

$$CR = \frac{CI}{RI} \tag{2}$$

When CR < 0.10, the consistency of the judgment matrix is considered acceptable; Otherwise, appropriate corrections should be made to the judgment matrix.

3.4 Calculation of the Weight Vector *W*

Since each column in the judgment matrix A approximates the distribution of the weights, the arithmetic mean of all the column vectors can be used to estimate the weight vector, i.e., Wi.

$$W_i = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}, \ i = 1,2, \dots, n \tag{3}$$

4. Analysis of Sanitary Landfill Site Selection Results

4.1 The Judgment Matrix, Weight Calculation and Consistency Indexes of the Target Layer (A) and the Criterion Layer (B_1-B_4) are Shown in Table 3

Table 3. Table of calculation results of target layer (A) and criterion layer (B_1-B_4)

A	B_1	B_2	B_3	B_4	W_i	λ_{max}	*CR*
B_1	1	4	1/3	2	0.2326	4.0284	0.0106
B_2	1/4	1	1/7	1/2	0.0670		
B_3	3	7	1	5	0.5791		
B_4	1/2	2	1/5	1	0.1213		

From the weighting results in Table 3, it can be seen that environmental protection (B_3) > construction cost (B_1) > site topography (B_4) > collection and transportation distance (B_2). Next, judgment matrices were constructed for the criterion layer (B_1-B_4) and the scheme layer (C_1-C_3) (i.e., the B-C layer judgment matrix), and the judgment matrices, weight calculations and consistency indicators are shown in Tables 4 to 7.

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Table 4. Table of calculation results for the criterion layer (B_1) and the scheme layer (C_1-C_3)

B_1	C_1	C_2	C_3	W_i	λ_{max}	CR
C_1	1	1/3	1/5	0.1096	3.0037	0.0036
C_2	3	1	1/2	0.3092		
C_3	5	2	1	0.5813		

Table 5. Table of calculation results for the criterion layer (B_2) and the scheme layer (C_1-C_3)

B_2	C_1	C_2	C_3	W_i	λ_{max}	CR
C_1	1	1/2	3	0.3092	3.0037	0.0036
C_2	2	1	5	0.5813		
C_3	1/3	1/5	1	0.1096		

Table 6. Table of calculation results for the criterion layer (B_3) and the scheme layer (C_1-C_3)

B_3	C_1	C_2	C_3	W_i	λ_{max}	CR
C_1	1	1/2	1/4	0.1429	3.0000	0.0000
C_2	2	1	1/2	0.2857		
C_3	4	2	1	0.5714		

Table 7. Table of calculation results for the criterion layer (B_4) and the scheme layer (C_1-C_3)

B_4	C_1	C_2	C_3	W_i	λ_{max}	CR
C_1	1	3	3	0.5889	3.0539	0.0518
C_2	1/3	1	2	0.2519		
C_3	1/3	1/2	1	0.1593		

According to the results of the consistency ratio CR of the judgment matrix of the criterion layer (B) and the scheme layer (C), the calculated results are less than 0.10, indicating that the ranking of the criterion layer (B) and the scheme layer (C) is valid and has good consistency, and the judgment matrices all meet the requirements.

4.2 Comprehensive Ranking of Landfill Site Weights

Based on the above calculation results, the weight ranking of the scheme layer (C) to the target layer (A) is collated and calculated, and the ranking results are shown in Table 8 below.

Table 8. Ranking of weights of scheme layer (C) to target layer (A)

Sort	The scheme layer (C)	W_i
1	C_3	0.4928
2	C_2	0.3069
3	C_1	0.2004

From the above table, it can be seen that the weighting of the elements in the scheme layer to the decision objective is Huangyu Town (C_3) > Yaojie Town (C_2) > Agan Town (C_1), then the site of Lanzhou municipal solid waste sanitary landfill should be chosen in Huangyu Town.

5. Conclusion

In the evaluation system of Lanzhou municipal solid waste sanitary landfill site, the influence weight of environmental protection on the target layer is the largest in the guideline layer, and the weight value of environmental protection is 0.5791, and the influence weight of collection and transportation distance on the target layer is the smallest, and the weight value of collection and transportation distance is 0.0670. Therefore, in the siting study of municipal solid waste sanitary landfill, we should consider whether the landfill will cause pollution to local surface water and groundwater, and whether there are national key environmental protection zones around the landfill. According to the analysis of analytic hierarchy process, the best location for municipal solid waste sanitary landfill in Lanzhou is Huangyu Town, and the evaluation results are basically in line with the actual situation. The evaluation method makes the study of municipal solid waste sanitary landfill site selection more objective and the results more scientific, effective, accurate and intuitive, which shows that the analytic hierarchy process is a well-established qualitative and quantitative evaluation method in landfill site selection and analysis.

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