Comparative Study on Landfill Type Selection of Rural Household Garbage Instead of Incineration by GAHP

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Abstract. In view of the problem of landfill type selection of rural household garbage landfills in China, the factors influencing the selection of rural household garbage landfill types were analyzed. Based on the analytic hierarchy process and group decision theory, a comparative model of landfill types was established for rural household garbage. Besides, the results of the questionnaire were analyzed through Yaahp software. According to the results, environmental friendliness, public satisfaction and operating cost are the main factors influencing the selection of rural household garbage landfill programs, and anaerobic and quasi-aerobic landfill programs are suitable for promotion in rural areas.

Keywords: rural household garbage, comparative, analytic hierarchy process, group decision theory.

1. Introduction

Rural household garbage are solid wastes produced by rural households in everyday life [1]. Rapid economic development improves the living standards, but meanwhile the household garbage increases year by year and becomes more diverse in kind, making disposal of household garbage a challenge [2]. Incineration of garbage is costly, while turning garbage into compost is not a favored choice for the population, and landfilling provides the ideal solution to disposal of household garbage in rural areas [3].

In China, the landfilling method of rural household garbage should not be the same as those adopted by cities. Anaerobic bioreactor landfills are stable and efficient, but require supply of oxygen and have high requirements for economic and technological conditions, thus not suitable for promotion in rural areas [4-6]. Aerobic bioreactors, Quasi-aerobic bioreactors and anaerobic quasi-aerobic bioreactors come as good back-up solutions.

Currently, there is no mature systems for comparison and selection of rural household garbage landfilling methods. Thus, finding a scientific and effective decision-making method is necessary and important. For objective decision-making problems, the analytic hierarchy process (AHP) provides a solution for qualitative and quantitative analysis, and the group decision method can integrate opinions from different experts, making the quantitative analysis more reasonable.
2. GAHP model

2.1. Principles and steps
All Analytical hierarchal process, also termed AHP, is a decision-making method that decomposes a decision-making problem into an object layer, a principle layer, an indicator layer and a solution layer, and then performs qualitative and quantitative analysis to make decisions [7]. Group analytical hierarchical process (GAHP) derives from AHP, and the major difference between the two is that GAHP integrates data from multiple experts and thus solves the problem of subjective judgement by one single expert.

Using AHP and GAHP to solve problems involves the following four steps: (1) establish a hierarchical structure; (2) construct a judgement matrix; (3) calculate the weight under a single standard; (4) calculate the weight of element combinations on each layer. The difference lies in the judgement matrix; i.e. in the GAHP method, the group decision-making consensus matrix should be built [8].

2.2. GAHP software Yaahp
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3. Construction of the landfill type comparison and selection model
For the problem of selection of landfill methods for rural household garbage, the landfilling solution is the objective layer of the decision model. Economic factors, environmental factors, social factors and technological innovation are the four major aspects that influence the decision-making, making up the criterion layer of the model. The economic factors include the investment and operational cost of the landfill; the social factors include the public satisfaction, developmental sustainability and utilization of resources; the environmental factors include the environmental-friendly nature and the stability cycle of the landfill; the major indicators of technological innovation include the advanced nature, stability and security of technology. Based on these analyses, the hierarchical decision model for selection of rural household garbage landfills is built, as shown in Figure 1.

![Figure 1. Hierarchical decision model](image-url)
4. Data collection and analysis

4.1. Data collection
The data in this study were collected through questionnaire surveys completed by a group of experts. Thus, the reliability of the decision result relies largely on the knowledge of the group of experts. Five experts in environmental science were invited, one professor of environmental engineering from a university in Taiyuan City, one senior engineer in solid waste processing from a design institute in Taiyuan, one professor in solid waste processing from a university in Chengdu, one senior engineer in landfill design from an environment company, one senior engineer in an environment monitoring station in Sichuan province.

4.2. Data analysis
The feedback data from experts in questionnaire surveys were input into the judgement matrix of Yaahp, the selection aggregation judgement matrix that combine data of different experts was established. To ensure the reciprocity of the matrix, the geometric mean method was used to establish the consensus matrix.

5. Result analysis

5.1. Construction of the judgement matrix
The judgement matrix of the objective layer A to the criterion layer B was labelled as A; the judgement matrix of the objective layer Bi to the index layer C was labelled as Bi, the judgement matrix of the index layer Ci to the solution layer D was labelled as Ci. The consensus matrix output by the Yaahp software was as follows:

\[
A = \begin{bmatrix}
1.0000 & 0.9883 & 0.4353 & 3.2023 \\
1.0118 & 1.0000 & 0.7071 & 2.6564 \\
2.2974 & 1.4142 & 1.0000 & 3.0876 \\
0.3123 & 0.3764 & 0.3239 & 1.0000 \\
\end{bmatrix}
\]

\[
B_1 = \begin{bmatrix}
1.0000 & 0.7579 \\
1.3195 & 1.0000 \\
4.4721 & 2.1689 \\
1.0000 & 0.4611 \\
\end{bmatrix}; \quad B_2 = \begin{bmatrix}
1.0000 & 0.4082 & 0.2236 \\
2.4495 & 1.0000 & 0.4611 \\
4.4721 & 2.1689 & 1.0000 \\
\end{bmatrix}.
\]

\[
C_1 = \begin{bmatrix}
1.0000 & 0.7155 & 2.2587 \\
1.9777 & 1.0000 & 2.3522 \\
0.4427 & 0.4251 & 1.0000 \\
1.1962 & 0.4251 & 1.0000 \\
\end{bmatrix}; \quad C_2 = \begin{bmatrix}
1.0000 & 0.3854 & 0.8360 \\
1.0000 & 2.3522 & 1.0000 \\
1.1962 & 0.4251 & 1.0000 \\
\end{bmatrix}.
\]

The weight vector that corresponds to each judgement matrix and the consistency ratio (C.R.) are shown in Table 1.
As Table 1 shows, the values of C.R. of all judgement matrices were below 0.1, indicating that the constructed judgement matrices met the requirements of consistency.

5.2. Calculation the combined weight
Based on summary of the weights on the upper and lower layer of the criterion layer, the combined weights of the indices C1~C10 were obtained. Among the indices on the index layer C, the environmental-friendliness index had the largest weight, reaching 0.2841, indicating that the experts agreed that the selection of rural household garbage landfilling methods should fully consider the environmental impacts. The second largest weight is the public satisfaction (C5), reaching 0.1518. As the education quality improves, the public attention paid to environmental problems increases. Therefore, in selection of rural household garbage landfill methods, the public satisfaction should be considered. The operational cost of landfills has the third largest weight. Unlike cities, the rural areas are short of capital support, so to find a method that incurs low operational costs is necessary.

5.3. Identifying the optimal solution
According to the weight coefficient of each judgement matrix, the corresponding weight of solutions D1~D3 output by the software Yaahp was obtained: (0.3128, 0.3364, 0.3508) T. The solution D3 (anaerobic quasi-aerobic landfill) had the largest weight, and thus was judged suitable for promotion in rural areas.

6. Conclusion
(1) The hierarchical analytical process and the group decision theory were combined to build the decision model for rural household garbage landfill selection, aiming to provide a basis for decision-making of solutions for rural household garbage landfilling.

(2) The sequence of influence of factors on the criterion layer on the selection of rural household garbage landfilling methods is: environmental factors>social factors> economic factors> technological innovation.

(3) Among the ten factors, the top three that have the largest impacts on the selection of landfill solutions are environmental-friendliness, public satisfaction, and operational cost;

(4) The software Yaahp was used to process the questionnaire data from five experts. The quantitative evaluation results were obtained, the problems were simplified, the decision-makers’ workload was reduced and the thus the proposed method was confirmed practical.
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