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Assessment of Medical Waste Treatment Technologies based on Analytic Network Process Method

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Abstract

The safety of medical waste treatment is an important part of maintaining the health of the group, and it is very crucial to choose an appropriate method of medical wastes management. Based on the understanding of the medical waste disposal methods and the consideration of the interdependence of indicators, the objective of this paper is to give a reasonable evaluation of the medical waste treatment alternatives by using Analytic Network Process (ANP). Finally, steam sterilization is the best method of medical waste management at this stage, so as to further maintain the health of the community and improve living standards of the people.

Keywords

medical waste, ANP, evaluation index.

1. Introduction

With the rapid development of science and technology, the medical and health services have also steadily grown in recent decades. But medical and healthcare wastes have sharply increased. In Poland, there are approximately 40,000 waste generators and each year they produce on average 45,000 tons of medical waste, of which more than 90% is classified as infectious. In the case of medical waste as a whole, hazardous wastes represent 10–25 % of the total medical wastes. Hazardous medical wastes include, but are not limited to, infectious, chemical and radioactive wastes and may pose various environmental and health risks[1].

Inappropriate medical waste management can cause environmental pollution. Besides, it can also give rise to rapid growth of insects, rodents and worms and lead to the spread of diseases caused by contaminated blood such as cholera, hepatitis and typhoid, in which people's lives are threatened. Correct disposal medical waste can not only reduce and avoid the waste of resources, and improve the irrational medical system, but also further protect society and environment and ensure the safety of citizens. Therefore, the proper and reasonable disposal medical wastes plays a vital role in medical and environmental management. At the same time, many scholars have conducted researches on medical wastes.

The researches on the medical wastes treatment technologies are mainly divided into two categories. One is to investigate the current situation of the medical treatment through surveys or personnel interviews. Patwary et al.[2] investigated the impacts of the environmental safety and potential risks, especially individuals who are currently working on medical wastes in Dhaka. Manga et al.[3] carried out a waste management system based on five surveys about health care facilities in southwestern Cameroon Assessments to identify current practices and areas for improvement; Ferreira and Teixeira [4] analyzed the medical wastes management practices in hospitals of the Algarve Region, Portugal, and assessed the risk perception of the healthcare staff and the risks to staff groups posed by waste management in these hospitals. Abd El-Salam [5] investigated medical wastes management in 8 Pride Hospitals in Egypt, to determine the overall wastes productivity and physicochemical

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characteristics. Rahmani, et al. [6]was to select the best infectious waste treatment alternative by Sustainability Assessment of Technologies (SAT) methodology.

The other category is based on the status quo, gives some solutions and gains the best disposal technology. Liu et al. [7] used VIKOR fuzzy multi-criteria decision-making to study HCW disposal methods; Liu et al.[8] considered the subjective and objective importance coefficient criteria of evaluation by MULTIMOORA method of the interval 2-tuple language variable (called ITL-MULTIMOORA) to select alternatives; Ata et al.[1] used SAT methodology to qualitatively and quantitatively evaluate infectious wastes; Chao et al.[9] presented a hybrid 2-tuple-induced TOPSIS decision method. The combination of 2-tuple induced distance operator and optimization technique was used to solve the problem.

Although academics on medical wastes disposal have made some achievements, they also have contributed to the research on methodologic assessment. However, the previous researches still have shortcomings and problems that need to be improved. The above methods are not only indicators considered incompletely, but the correlation between indicators is not taken into account. In accordance with the recursion of indexes and the interdependence between indicators, the focus of this paper will give an appropriate evaluation of medical wastes treatment technologies and choose the best disposal technology, so as to further maintain the health of the populations.

2. Problem Presentation

Unreasonable waste disposal, directly free to throw away, causes very serious losses. It will pollute the soil, water, then the disease will come. Therefore, the proper and reasonable disposal of medical waste is of great importance.

2.1. Consideration of Multi-objective Decision-making(MODM) in the Evaluation of Medical Wastes Treatment Methods

Multi-objective decision-making refers to the selection of a scheme, which needs to satisfy the satisfaction of multiple objectives. This was proposed by VonNouma and Oskar in 1944.For example, when building commercial housing, we need good lighting, convenient transportation and moderate cost. These goals interact and conflict with each other. Choosing the right housing, that is, making the final decision, is a complex project. This is also known as the multi-objective decision problem.

In this paper, there are many ways to dispose of medical wastes. However, each hospital system may need to dispose of wastes without any pollution and bad impact on the environment and society. Besides that, the hospital also should satisfy high-tech, low-cost goals. This is a MODM problem, meeting a number of goals, and this is a very complicated process.

2.2. Consideration of the Interdependence between Indicators of the Medical Wastes Treatment Methods

To data, many scholars have made relevant researches on the rational use of medical waste disposal methods. However, in my field of vision, scholars at home and abroad are still not very mature in the research on this aspect. The foreign research system for the evaluation of medical wastes disposal methods has basically taken shape. However, it’s a few researches that consider the recursion of indicators and interdependence of evaluation indexes. Based on the recursion of indicators and the interdependence between them, a reasonable evaluation of medical waste disposal methods is made and the best disposal technique is selected.

Based on selecting lots of indicators, taking the interdependence between indicators into account and satisfying the various constraints, this paper chooses the optimal medical wastes

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treatment technology, thereby establishes a systematic and comprehensive management system to adapt to the changes in social environment.

3. Methodology

3.1. ANP Method

The Analytic Network Process (ANP) method was proposed on the basis of Analytic Hierarchy Process(AHP)by American scholar Professor Saaty in 1996 [10], which is a special case of AHP. AHP is a method that can be used to establish measures in the physical and social fields. It is a non-linear framework that can represent hierarchical relationships [11], but it does not take into account whether the elements in the problem are independent. the ANP method allows complex interactions between elements dependency, as shown in Figure 1. Figure 1 is the structure diagram of AHP and ANP. In general, ANP can provide an overall framework for handling decisions, rather than making assumptions about the independence of lower-level elements [11].

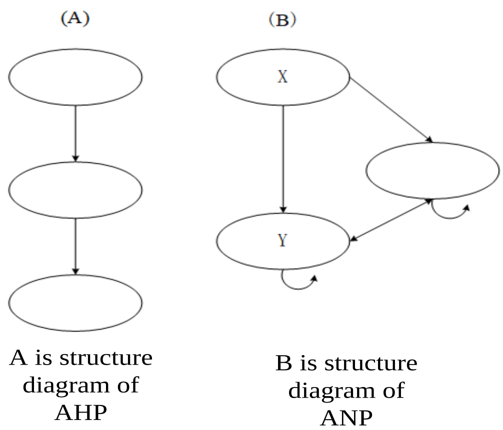

Figure 1: The structure diagrams of AHP and ANP

3.2. Construction of Evaluation Index System

The index is very important to the evaluation of medical waste treatment technology. According to the basic principles of "systematic principles of medical wastes disposal, typical principles of indicators, concise scientific principles, comparable and operated principles and comprehensive principles"(These are related to the evaluation index system of medical wastes treatment technologies), and the main influence factors about constructing the evaluation of medical wastes treatment technologies , there are some primary indexes as follows: Technical performance, Environment, Economic, Social[1,12]. Based on a certain criterion, experts in relevant fields decide the impact of the same level of indicators, and mark 1-9 degree of influence and determine the weight. Using ANP method ranks medical wastes treatment technologies, and the best results can be gained. This paper's index system is shown in Table 1.

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Table 1: Evaluation index system of medical waste disposal methods

Indicator	Sub-indicator	Description
Technical performance	T1 Treatment capacity	The amount of waste that can be disposed of by the disposal system within a certain period of time.
	T2 Treatment efficiency	Medical waste disposal system can achieve the efficiency of treating microorganisms and pathogens.
	T3 Reliability	The operation, maintenance and repair of the medical waste disposal system are mainly used to reflect the maturity of the technology.
	T4 Security	There is an emergency plan for the medical waste disposal system. In emergency, it can be displayed by various alarm devices of the system, and the emergency plan is activated to ensure the safety of the system.
Economic	Ec1 Capital cost of technology	The cost of technology project investment.
	Ec2 Capital cost of all accessories and related equipment	The cost of purchasing technical equipment.
	Ec3 Operation and maintenance costs	The cost of maintenance and repair of medical waste disposal technical equipment.
	Ec4 Cost of income	Can reflect the level of profitability of technical projects.
Social	S1 Public acceptance	The public's rejection and acceptance of the medical waste disposal technology currently in use.
	S2 Policy level	The medical waste disposal technology used is supported by the government.
	S3Technology acquisition	The background of the technology supplier, the degree of commercialization and the way of introduction determine the past difficulty of the technology.
Environment	En1 Use of hazardous materials	No matter what kind of disposal technology, it will produce toxic and harmful gases, liquids or solids, which will generally be measured by the type and quantity produced.
	En2 Emission secondary pollution	Harmful substances are not cleaned after pollution control treatment, and are still discharged. The degree of secondary pollution of the discharge to the environment.
	En3 Impact on the health of surroundings	The use of disposal technology is harmful to the health of surrounding residents.
	En4 Noise	The sound is generated by equipment when operating disposal technology.

Consistent with the original network structure of the element, the impact relationship between indicators is determined, mainly to determine whether the indicators are internally independent, and whether there is interdependence and feedback. The specific situation is shown in Figure 2.

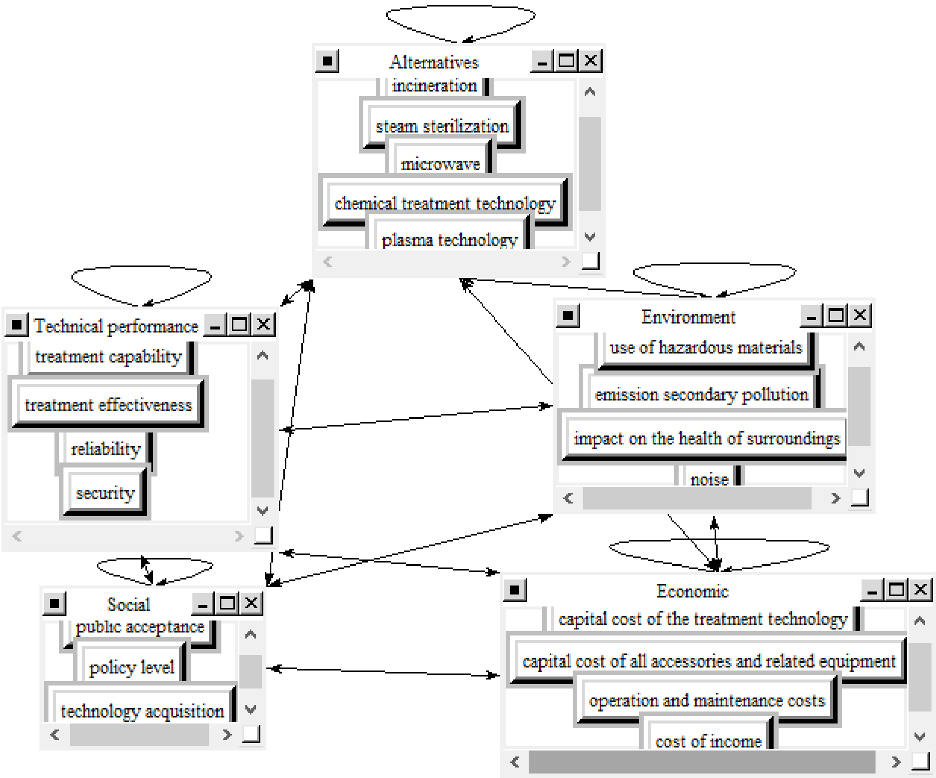

Figure 2: Medical waste treatment technologies evaluation index diagram

3.3. ANP Network Model

In this section, the ANP method is proposed to solve the problem of medical waste disposal technology selection. The ANP network model is shown in Figure 3.

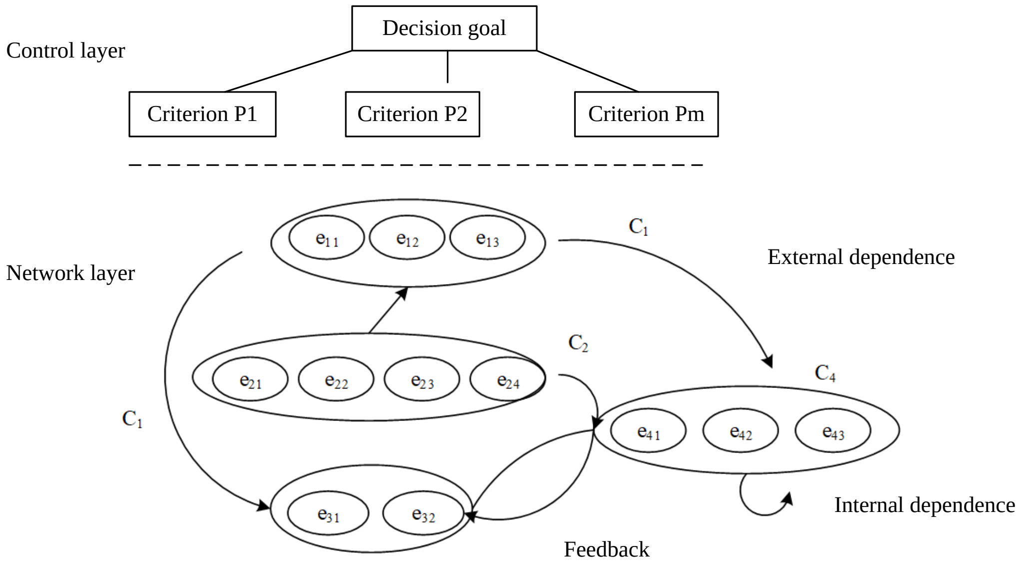

Figure 3: ANP network model

Under each control criterion, through the indirect dominance or direct dominance, the elements of the same level are compared one by one to obtain the judgment matrix. $P_s\left(s=1,2,\cdots,m\right)$ is main criteria, and the element $e_{j1}\left(l=1,2,\cdots,n_j\right)$ of element group C_j will be the Sub-criteria.

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The required judgment matrix can be obtained according to the degree of mutual influence of the elements of C_i on e_{j1}, the required judgment matrix is obtained. Also the normalized eigenvalues $\left(W_{i1}^{jl}, W_{i2}^{jl}, \cdots, W_{in_l}^{jl}\right)^T$ is given. Similarly, compare each element in C_i and C_j in pairs, and finally we can summarize all the normalized eigenvalues in the matrix W_{ij}.

In the same way, P_s is still used as the main criterion, and the internal and external relationships between each element are compared in sequence to obtain an unweighted super matrix W_s, which is Eq.(1).

$$
\begin{array}{ccc}
 & & \begin{array}{cccc} C_1 & C_2 & \cdots & C_N \\ e_{11}e_{12}\cdots e_{1n_1} & e_{21}e_{22}\cdots e_{2n_2} & \cdots & e_{N1}e_{N2}\cdots e_{Nn_N} \end{array} \\
W_s = & \begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_N \end{array}\ \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1n_1} \\ e_{21} \\ e_{22} \\ \vdots \\ e_{2n_2} \\ \vdots \\ e_{N1} \\ e_{N2} \\ \vdots \\ e_{N_n} \end{array} & \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1N} \\ W_{12} & W_{22} & \cdots & W_{2N} \\ \vdots & \vdots & \vdots & \vdots \\ W_{N1} & W_{N2} & \cdots & W_{NN} \end{bmatrix}
\end{array} \tag{1}
$$

$$
W_{ij} = \begin{bmatrix} W_{i1}^{\ j1} & W_{i1}^{\ j2} & \cdots & W_{i1}^{\ jn_j} \\ W_{i2}^{\ j1} & W_{i2}^{\ j2} & \cdots & W_{i2}^{\ jn_j} \\ \vdots & \vdots & \vdots & \vdots \\ W_{in_1}^{\ j1} & W_{in_2}^{\ j2} & \cdots & W_{in_j}^{\ jn_j} \end{bmatrix} \tag{2}
$$

Then, we transform other criteria as the main criteria to obtain unweighted super matrices, respectively.

Taking P_s as the main criterion and C_j as the sub-criterion, the element groups are compared in pairs to obtain the judgment matrix a_j, which is normalized to get the normalized feature vector $\left(a_{1j}, a_{2j}, a_{3j}\right)^T$.

$$
\begin{array}{ccc}
 & \begin{array}{ccccc} C_j & C_1 & C_2 & \cdots & C_N \end{array} & \text{Normalized eigenvectors} \\
a_{ij} = \begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_N \end{array} & \begin{bmatrix} a_{11}^j & a_{12}^j & \cdots & a_{1N}^j \\ a_{21}^j & a_{22}^j & \cdots & a_{2N}^j \\ \vdots & \vdots & & \vdots \\ a_{N1}^j & a_{N2}^j & \cdots & a_{NN}^j \end{bmatrix} \longrightarrow & \begin{array}{c} a_{1j} \\ a_{2j} \\ \vdots \\ a_{Nj} \end{array}
\end{array} \tag{3}
$$

Then we can get the weighting matrix A_s under a certain criterion.

$$
A_s = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1N} \\ a_{21} & a_{22} & \cdots & a_{2N} \\ \vdots & \vdots & \vdots & \vdots \\ a_{N1} & a_{N2} & \cdots & a_{NN} \end{bmatrix} \tag{4}
$$

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Then the weighted super matrix W_s^w is Equation (5).

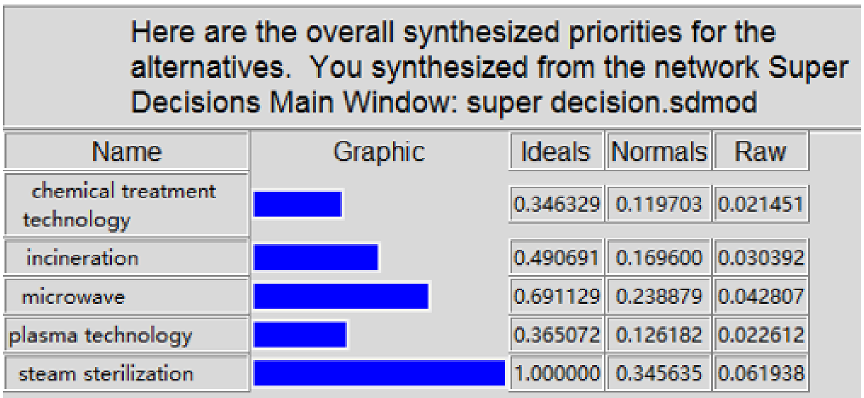
$$W_s^w = A_s W_s \tag{5}$$

The weighted supermatrix is processed by power until the value of each column does not change, and a limit supermatrix is obtained, which is used to reflect the order of the influence of various factors.

4. Illustrative Example

Hospital A, a Grade-A hospital located in X City, S Province, has more than 1,000 beds, with 256-layer high-end spiral CT, various scanning systems and analysis systems. There are many departments, such as Respiratory Medicine, Cardiology, Urology, Gynecology and so on, a total of 21 administrative functions departments and 51 clinical and medical departments. Like this hospital there are about 25-30 barrels a day of medical waste at a rate of about 25 kg a barrel for a total of 375 kg to 450 kg. Hospital A has been primarily disposing of medical wastes internally using incineration, steam sterilization, microwave, chemical treatment technology and plasma technology. The indicators in the model are decided by experts. In this paper, there are 5 experts from medical waste managers, government agents and environmental protection specialists and other field personnel. According to the information collected from the disposal technologies of the hospitals, the expert group determines the interaction of each indicator. Based on the comparison of evaluation criterion between two medical wastes disposal methods under one criteria, we can draw multiple judgment matrices, such as matrix (6). Using the super decision software to solve the model, the weight of the unweighted matrix is obtained. After that we can normalize the unweighted matrix to obtain the weighted hyper matrix and the limit super matrix. Finally, get the result of software calculation in Figure 4 and steam sterilization is the most suitable medical wastes treatment technology after comparison.

$$W_s = \begin{bmatrix} 1 & 1/5 & 3 & 4 \\ 5 & 1 & 7 & 6 \\ 1/3 & 1/7 & 1 & 2 \\ 1/4 & 1/6 & 1/2 & 1 \end{bmatrix} \tag{6}$$


Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: super decision.sdmod

Name	Graphic	Ideals	Normals	Raw
chemical treatment technology		0.346329	0.119703	0.021451
incineration		0.490691	0.169600	0.030392
microwave		0.691129	0.238879	0.042807
plasma technology		0.365072	0.126182	0.022612
steam sterilization		1.000000	0.345635	0.061938

Figure 4: Medical waste treatment technologies evaluation index comprehensive weight

(1) According to the global weights in Figure 4, the Impact on the health of surroundings (En3) is the most important indicator affecting the weight of 0.514. In addition, the production of toxic and harmful substances and the discharge of secondary pollution are also very important. The results of these studies indicate that experts believe that when choosing the best medical waste disposal technology, the environment is the most important of all indicators. No matter what disposal technology is used, the dimension of environment (En) must never be ignored.

(2) Figure 4 shows that when choosing the best medical waste disposal technology, we mainly consider the two dimensions of environment (En) and technical performance (T), which have the greatest impact on the choice of disposal technology. In the technical performance, we must first consider the Reliability T3 and Security (T4). Only technologies that are mature and have countermeasures in an emergency can be used with confidence.

It can be seen from the results of the medical waste disposal technology of Hospital A. Now when choosing technology, we first consider whether the environment we live in will harm the health of residents, and second, we must assess whether the various indicators of the technology can meet the standards. This result is the same as the research results of many scholars at home and abroad, but the application of the method is more in line with the actual situation. It considers the interdependence between indicators comprehensively and is more adaptable to the constantly changing and developing society.

5. Conclusion

On the basis of previous studies on the evaluation of medical wastes treatment technologies, this paper uses the expert scoring to determine the weights in terms of the interdependence between the indicators. Afterwards, the evaluation system of medical wastes treatment technologies and ANP model are built. Finally, the model is solved by super decision software. The result reflects the feasibility and operability of the system and model, and it's better to make up the deficiency that ignoring the interdependence between the indicators in existing papers. The aim is to reduce the impact of medical wastes on environment and society and improve the medical and health management system simultaneously. In future research, the proposed model can be modified by objective or the combination of subjective and objective to determine the weights before it is applied to solve the related problems.

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