Research

Prioritizing the Options for Health-care waste Management in Qazvin: Using a Multi-Criteria Decision Making Approach

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ABSTRACT

Due to an increase in population and the number of health-care centers and increasing use of disposable medical products over the last decades, there has been a remarkable increase in health-care wastes which can cause numerous problems if they are not managed properly. The present study was carried out in order to select the best method to manage health-care wastes through multi-criteria decision making (MCDM) approaches. The present study was a descriptive-applied research that was conducted in Qazvin in 2016. The study sample consisted of 28 experts belonging to 5 groups that were selected through purposefully sampling method. After the questionnaire was designed, Analytic Hierarchy Process (AHP) was employed to measure the weight of the criteria. Afterward, TOPSIS method was utilized to rank different disposal methods of health-care waste. Based on the opinion of experts of the 5 groups about the weight of the criteria and the results of the weighting phase, it was indicated that the highest weight was related to air residuals criterion and environmental impacts, and the lowest to the cost criterion. According to the study inclusion criteria, the final results of the ranking are respectively irradiation (0.83), microwave (0.79), steam sterilization (autoclave) (0.75), chemical disinfection (0.55), sanitary landfill (0.35), and finally incineration (0.29). The results of the current study indicated that according to the groups under investigation, the best methods to dispose of health-care wastes in Qazvin are irradiation and microwave. According to this finding, the policymakers can plan to make more use of these two methods in order to dispose and disinfect health-care wastes.

Key words: Waste Management, Multi-criteria Decision-making approach, Health-care Waste, Waste Disinfection, Medical waste, Disposal methods, Iran

1. INTRODUCTION

Health-care wastes are a special category of solid wastes that are produced during the processes of diagnosis, treatment, or immunization of humans and animals and in the studies related to production or examination of biological materials (1, 2). Over the past two decades, human activities and changes in lifestyle and consumption patterns have led to production of a huge volume of different types of municipal solid wastes including household wastes such as kitchen wastes, sewage residuals, commercial and industrial residuals, and health-care (hospital) wastes that have become one of the biggest environmental problems in urban areas (3, 4). Due to an increase in population and the number of health-care centers and increasing use of disposable medical products over the last decades, there has been a remarkable increase in health-care wastes which can cause numerous problems if they are not managed properly (5, 6). Mismanagement of these wastes can have adverse effects on human health, environmental pollution (water, air, soil, etc.) and bad

odors. Health effects caused by dealing with hazardous health-care wastes include mutagenic and carcinogenic problems, respiratory injuries, complications of the central nervous system, and reproductive system damage (7-9). Unfortunately, over the last years, in developing countries such as Iran, little attention has been paid to appropriate management of health-care wastes, and in some countries, hospital wastes are still mixed and buried with household wastes without being processed or separated (7-10). Different studies have focused on appropriate methods of managing health-care wastes. The results of such studies have indicated that a large number of internal and external factors affect the management of clinical wastes and the activities conducted at the hospitals. The most significant weakness has been reported to be weakness in separating the wastes (11). Moreover, the results of different studies indicated the lack of an integrated approach to policymaking and managing the hospital and health-care wastes at the highest levels of decision making (12). Approaches like Total Quality Management (TQM) and FMEA model have been recommended for disposal of health-care wastes and infectious hospital wastes (10, 13). Furthermore, the results of a study that focused on determining the most appropriate method to dispose of health-care wastes in Istanbul showed that steam sterilization was the best option, followed by the methods of microwave, incineration, and sanitary landfill, respectively (14). Despite the fact that the current methods of managing health-care wastes are different from one health-care center to another (15, 16), it is necessary to take different factors including public health, economic situation, social aspect, law and regulations, and hospital management, and interaction and the relationship among different factors into consideration in order to set up an appropriate management system for health-care wastes. Most previous studies have focused on one or some factors without considering the interaction and relationship among various factors (17, 18). Qazvin province has 14 hospitals and 1370 hospital beds, which leads to the production of 5122 kg health-care wastes and thus 1533 kg infectious wastes which are disinfected with autoclave, hydroclave, and chemiclave devices that are manufactured in Iran or imported from other countries (19). These data indicate the significance of paying attention to the management of health-care wastes in this province. Therefore, the present study used a multi-criteria decision-making (MCDM) approach to choosing the best method to manage hospital wastes in the hospitals of Qazvin.

2. MATERIALS AND METHODS

The present study was a descriptive-applied survey that was conducted in Qazvin in 2016. The study sample consisted of 28 experts who belonged to 5 groups (Health Deputy Experts (HDE), Environmental Protection Agency Experts (EPAE), Waste Management Organization Experts (WMOE), Hospital Environmental Health Experts (HEHE), and Faculty Members (FM). In selecting the study sample, purposefully sampling method was employed. Experts who have relevant College education with at least B.Sc. degree and more than 5 years of working experience and willingness to participate in the study were included in this study.

In the beginning, the disposal methods of health-care wastes and effective and significant criteria in doing so were identified by reviewing the studies, research, and theses that had focused on this issue. The output of this phase was a list of effective factors involved in disposal of wastes and appropriate disposal methods of health-care wastes. In the next phase, the research instrument was designed. In so doing, relevant studies were reviewed and combined with some stages and corrective opinions and points recommended by experts were applied. Afterward, all alternatives that were designed in an initial questionnaire were given to a group of experts and professors of related majors and were finally designed in the form of a paired comparisons questionnaire whose content validity was evaluated through the professors' opinions, and its reliability was affirmed based on inconsistency rate of 0.013. In the present study, Analytic Hierarchy Process (AHP) method was used to measure the weight of the criteria. This method is based on paired or binary comparison of the decision-making indices or options (20). In AHP environment; however, the decision maker cannot express his/her certain preferences, but he/she can only make a judgment based on his/her feeling and understanding. In other words, this approach cannot correctly reflect uncertainty in human thought. In terms of fuzzy sets, the ratio that is given to a decision maker is a fuzzy number through which a membership set is defined. Here, the membership function defines the degree to which the components belong to the preferences set in a judgment space (21). In the present study; therefore, fuzzy AHP was employed to determine the weights of the criteria. The experts' responses to the paired comparisons were collected based on terms and a 9-point scale; therefore, their responses needed to convert into a form that could be analyzed. The phase after the conversion of the experts' responses into fuzzy numbers was the integration of their responses. In so doing, the method proposed by Buckley was employed. According to Buckley, the following formula (Equation 1) can be used in order to integrate the experts' opinions (N experts) (12). Where U_{ij} is a triangular fuzzy number.

Equation 1:

$$U_{ij} = (l_{ij}, m_{ij}, u_{ij}) : l_{ij} \leq m_{ij} \leq u_{ij} \in [1.9, 9]$$

$$l_{ij} = \min(B_{ijn}), \qquad m_{ij} = \sqrt[n]{\prod_1^n B_{inj}} \qquad u_{ij} = \max(B_{ijn})$$

Before the weights of the criteria were calculated through fuzzy AHP, the inconsistency ratio of the experts' responses needed to be measured. When there are more than four criteria, the maximum ratio that is acceptable is 0.1. After the acceptability of the inconsistency ratio of the data was assured, the weight of the data was calculated. In so doing, Chang's Extent Analysis Method (EA), which is the most known and widely used method to solve fuzzy hierarchical analysis problems, was employed. Finally, after the weights of the criteria were calculated, TOPSIS method was used to rank different disposal methods of health-care wastes. This model is one of the best widely-used multi-criteria decision models. In this method, *m* alternatives (here waste disposal methods) are evaluated through decision-making matrix using *n* criteria. This technique is based on this concept that the selected alternative needs to have the minimum distance from the

positive ideal solution (the best possible state, A^+_j) and the maximum distance from the negative ideal solution (the worst possible state, A^+_j) (21). The questionnaires were distributed among the participants, and necessary explanations on how to complete them were given to them. In order to analyze the data obtained from AHP questionnaires, EC backup software developed by Saati et al. (22), Excel and Lingo were utilized.

3. RESULTS AND DISCUSSION

The study sample consisted of 17 men (60%) and 11 women (40%), 21 (75) were married and 7 (25%) were single. The participants' mean age was 36.9± 6.0 years, their mean work experience was 13.3± 6.8 years, and their experience in their current position was 9± 6.9 years. Most of the participants (15 individuals, 53.6%) had a bachelor's degree (Table 1).

Table 1. Participants' demographic information

Item	Background variable	Frequency	Percentage
Gender	Man	17	60.7
	Woman	11	39.3
Marital status	Married	21	75
	Single	7	25
Degree	BSc	15	53.5
	MSc	10	35.8
	PhD	3	10.7
Field of study	Environmental health engineering	24	85.8
	Health-care services management	2	7.1
	Natural resources engineering	2	7.1

After related literature was reviewed and the experts' opinions were referred to, about 12 number of criteria that are effective in the disposal of health-care wastes were determined which are presented in Table 2. Moreover, 6 methods (alternatives) of hospital waste disposal were identified which are showed in Table 3. After data analysis,

the results of weighting the criteria were reported in Table 2. According to the experts of the five groups, the highest weight was related to the criteria of air residuals and environmental impacts and the lowest weight was related to the criterion of cost. In addition, the inconsistency ratio calculated in this phase was 0.013 (Diagram 1).

Table 2. The mean score of each criterion according to the experts using MCDM approach

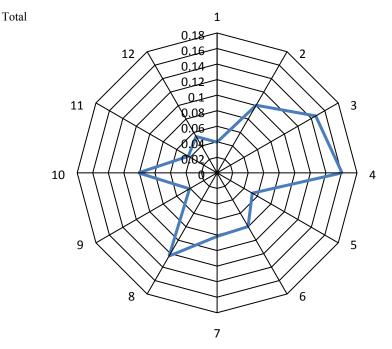| Code	Groups	HDE	FM	EPAE	HEHE	WMOE	Total	Rank
	Criteria							
1	Cost	0.03	0.014	0.105	0.03	0.046	0.0395	12
2	Solid residuals and environmental impacts	0.081	0.124	0.089	0.115	0..179	0.1005	5
3	Water residuals and environmental impacts	0.145	0.186	0.136	0.219	0.175	0.1465	2
4	Air residuals and environmental impacts	0.165	0.178	0.154	0.08	0.203	0.016075	1
5	Odor	0.05	0.035	0.045	0.028	0.033	0.05225	9
6	Release with health effects	0.055	0.125	0.125	0.087	0.081	0.07075	7
7	Reliability	0.096	0.07	0.042	0.075	0.039	0.08175	6
8	Treatment effectiveness	0.169	0.073	0.14	0.102	0.064	0.1235	3
9	Level of automation	0.034	0.025	0.047	0.021	0.031	0.041	11
10	Occupational hazards occurrence frequency	0.099	0.088	0.097	0.121	0.076	0.10125	4
11	Public acceptance obstacles	0.031	0.04	0.021	0.04	0.033	0.04275	10
12	Land requirement	0.045	0.042	0.024	0.083	0.039	0.054	8
---	Inconsistency ratio	0.04	0.08	0.1	0.07	0.06	0.013	---

Diagram 1. The mean score of each criterion according to the experts though MCDM approach

The weights that were obtained in AHP phase were used to rank the methods of waste disposal (alternatives) using TOPSIS method. The results of TOPSIS method according to the experts' opinion are presented in Table 3.

Table 3. Ranking waste disposal methods according to the experts using TOPSIS method

Code	Groups Alternatives	HDE	FM	EPAE	HEHE	WMOE	Total	Rank
1	Incineration	0.14677	0.58691	0.33150	0.30235	0.73842	0.29318	6
2	Steam sterilization	0.5693	0.47781	0.82836	0.75919	0.56444	0.75934	3
3	Microwave	0.52756	0.48348	0.94077	0.82268	0.65640	0.79408	2
4	Sanitary landfill	0.60466	0.48751	0.14989	0.34382	0.16812	0.35990	5
5	Chemical disinfection	0.49162	0.42069	0.55257	0.45142	0.44577	0.55447	4
6	Irradiation	0.68275	0.40573	0.82105	0.65580	0.50159	0.83974	1

The geometric mean method was employed to calculate the mean of the priorities stated by the experts, and finally, the disposal methods were ranked. According to the studied criteria, the final results of the ranking are respectively irradiation, microwave, steam sterilization (autoclave), chemical disinfection, sanitary landfill, and finally incineration (Diagram 2).
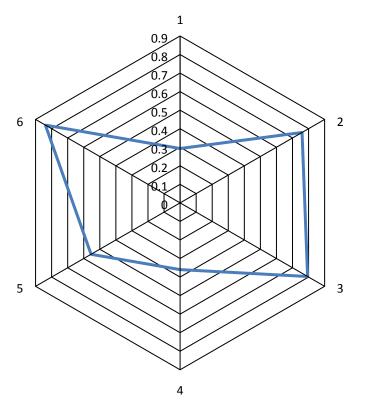
Diagram 2. Ranking waste disposal methods according to the experts using TOPSIS method

The present study was aimed at investigating different options for management of health-care wastes in Qazvin and choosing the best method of waste disposal through MCDM approach. In so doing, 12 different criteria were considered in ranking the waste disposal methods, among which the participants gave the highest score respectively to the three criteria namely air residuals and environmental impacts, water residuals and environmental impacts, and treatment effectiveness. Finally, among the common methods of waste disposal, the methods of irradiation, microwave, steam sterilization (autoclave), chemical disinfection, sanitary landfill, and incineration were respectively considered to be appropriate for Qazvin. Irradiation can penetrate in the bags and containers of wastes. As a complementary tool to be used alongside other methods, fatal ultraviolet rays are used to destroy airborne microorganisms, with this difference that it cannot penetrate into the packages of wastes (23). As a common method to disinfect health-care wastes, microwave method reduces the volume of the wastes and is useful for unknown wastes. This method; however, requires a high initial investment, and thus is not suitable for all kinds of waste (24). In a study carried out in Turkey, steam sterilization method was the best method, followed by microwave method. In that study, the researchers concluded that steam sterilization had the lowest impact on the environment. Due to its high cost and its side effects on the environment, incineration method was ranked third (14). In the present study, incineration method was ranked as the last method, which can be due to the facts that it leads to a high level of air pollution, it produces secondary hazardous materials, it is difficult to find the location to carry out incineration, and it involves high construction and utilization costs (24). Research has indicated that reducing waste production, controlling the gas pollutants released by incinerators, and using alternative methods instead of incineration are among the most important challenges in the management of health-care wastes in most countries (12, 25). Studies have also indicated that a lot of hospital waste management methods that are mostly practiced in less developed countries are not accepted by the World Health Organization (26). Hospitals and health-care centers are the most important places where hospital wastes are produced; therefore, hospital wastes are highly important (27). A large portion of hospital wastes are safe materials, and only 20-40% of these wastes are hazardous and chemical, which can be disinfected and disposed of through hospital waste management. According to the conditions and type of wastes, a single and comprehensive method should be used to dispose of hazardous and chemical wastes, which depends on different circumstances of societies (28). The results of studies carried out in advanced countries indicated that the amount and type of health-care wastes in the health-care centers determine the waste disposal plans and programs. In addition, much attention is paid to physical, economic, and environmental factors, followed by the proposal of the society's guideline on hospital waste management (29, 30). The numbers studied by experts in collected data (Confined to a city) may limit generalization of our results to other cities is one of limitations of this study.

4. CONCLUSION

According to the selected criteria, the results of the present

study indicated that the experts believed that irradiation is the best method to dispose of health-care wastes in Qazvin. At present, health-care wastes in Qazvin are disinfected with autoclave, hydroclave, and chemiclave devices that are manufactured in Iran or imported from other countries. According to the results of the present study, policymakers in the field of disposing and disinfecting health-care wastes are recommended to use methods like irradiation and microwave in disposing of hospital wastes.

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AUTHORS CONTRIBUTION

All the authors had a role in designing the study. The first author had the role in conducting the data analysis and interpretation of data. All the authors contributed to the data acquisition and write the preliminary draft of the manuscript.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interests with respect to the authorship and/or publication of this paper.

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