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EVALUATION OF SOLID WASTE TREATMENT METHODS IN LIBYA BY USING THE ANALYTIC HIERARCHY PROCESS

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Abstract: *Evaluation and selection of the appropriate method for solid waste treatment (SWT) in Libya are a complex problem and require an extensive evaluation process. This is because it is very difficult to develop a selection criterion that can precisely describe the preference of one method over another. Waste management is the collection, transport, treatment, recycling or disposal and monitoring waste materials. In this paper, four treatment systems for waste management in Libya are evaluated using the analytic hierarchy process (AHP) in respect to four main criteria and twenty-two sub-criteria. The treatment systems for waste management are anaerobic digestion, landfilling, incineration and compost. The selected criteria used in the evaluation of four treatment systems are environmental impacts, socio-cultural aspects, technical aspects and economic aspects. According to the evaluation, anaerobic digestion ranks the highest in classification in Libya. Compost ranks higher than landfilling and incineration. Furthermore, it should be noted that the rank of waste treatment systems can be changed according to the future technological developments.*

Key words: *Waste management, multi-criteria evaluation, AHP, Libya.*

1. Introduction

During the earliest periods, solid wastes were conveniently and unobtrusively disposed in large open land spaces, as the density of the population was low. As the population and economic growth increases, the solid household waste also increases. However, the population and economic growth not only lead to an increase in volume

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of solid household waste but also to great changes in its specification and contents (Najjar et al., 2015). The concept of eliminating waste completely is highly unrealistic. However, the best approach is to handle solid waste in such a manner that does not damage the environment, while utilizing methods supported by the denizens of the community who are directly impacted by the solid waste management (SWM) program in an area (Khan & Faisal, 2008). Therefore, waste management is a priority issue regarding protection of the environment and conservation of natural resources.

Libya is a north African country located along the southern coast of the Mediterranean basin. Its total land area is about 1.8 million km2, most of which (95%) is a desert, whereas the rest is either rangeland (4%), or agricultural land (0.5%), and less than 0.5% is a scattered forested area. Due to rapid expansion of industry, urbanization and increasing population, particularly in large cities which are located on the coast, has increased the amount of solid waste generated in Libya significantly (Badi et al., 2016). In Libya issues related to sound municipal solid waste (MSW) management including waste reduction and disposal have not been addressed adequately and the collection and the separation treatment of solid waste are still neglected.

In this paper, criteria for the assessment of the municipal waste management technologies are analyzed and evaluated. The technology assessment indices calculated with these methods were applied as criterions for multi-criteria analysis, which evaluates individual variants of municipal waste management systems. Indices evaluating the performance of the system can be determined with due regard to the technical, environmental, economic, social and other objectives, bearing in mind specific features of the area involved.

The aim of this study is to evaluate different waste management methods and their applicability in Libya based on Multi-Criteria Decision Analysis (MCDA). The common methods used in this study are those recommended in the waste management laws and regulations, such as composting, anaerobic digestion, incineration with thermal energy recovery (electricity and heat), and landfill without any form of energy recovery.

2. Literature review

This literature review studies and investigates various waste management methods and a multi-criteria decision analysis including waste reduction and disposal that is applied to the SWM.

Javaheri et al. (2006) presented study includes multi criteria evaluation method under the name of weighted linear combination by using geographical information technology to evaluate the suitability of the vicinity of Giroft city in Kerman province of Iran for landfill. The major criteria used in the study were geomorphologic, hydrologic, humanistic and land use. The results of the study were afford strategy to the decision makers of Giroft city by a variety of options (Javaheri et al., 2006).

Abd Manaf et al. (2009) evaluated the generation, characteristics and management of solid waste in Malaysia. It was concluded that the efficiency of solid waste management in Malaysia will be increased towards achieving Vision 2020 as a developed country (Abd Manaf et al., 2009). A case study was conducted by Sawalem et al. (2009) to evaluate hospital waste management in Libya. The study found that several factors such as the type of healthcare establishment, level of instrumentation and location affect waste generation rates. The results showed that the highest generation rates at Tripoli medical center are attributed to a larger number of patients due to being in the capital of Libya (Sawalem et al., 2009).

Gebril et al. (2010) presented an overview of the current SWM practices in Benghazi, Libya. The objective of the study was to investigate the current practices and challenges that faced MSW management in Benghazi. It was found that several issues affected in the SWM such as lack of suitable facilities and inadequate management and technical skills, improper bin collection and route planning (Gebril et al., 2010). Generowicz et al. (2011) combined the best available techniques, technology quality method and multi-criteria analysis in order to develop indices for evaluating municipal waste management systems. The results showed that incineration of waste is much more beneficial than disposal (Generowicz et al., 2011).

Tabasi and Marthandan (2013) presented an overview on the existing researches in the area of clinical waste management. The objective of the study was to investigate different findings regarding associated factors on quantity of waste generation to find, integrate and enhance accessibility to hospital key factors in waste generation forecasting. The results showed that the number of patients, number of beds, bed occupancy rate and type of hospitals were the most important factors in waste generation (Tabasi & Marthandan, 2013). Ismail & Latifah (2013) investigated the challenges which can be faced to find a suitable place for future landfill in Malaysia. Based on the fact that limited space is available for landfill development, the conclusion of the study was that, landfill cannot be the ultimate option for much longer (Ismail & Latifah, 2013).

A study was conducted by Gebril et al. (2010) to determine the causes of solid waste pollution in Benghazi City, in Libya and its surrounding areas. The results showed that solid waste pollution in the city and its surrounding areas is the outcome of poor planning and environmental management, population growth, lack of hardware and equipment for the collection and transport of waste from the city to the landfill site (Ali, 2014). Hamad et al. (2014) presented an overview on solid waste that can be used as a source of bioenergy in Libya including industrial solid waste and health care wastes as biomass sources. The aim of the study was to investigate whether or not solid waste can be used as a source of bioenergy in Libya. The results showed that organic matter represents 59% of waste, followed by paper–cardboard 12%, plastic 8%, miscellaneous 8%, metals7%, glass4%, and wood 2%. The technology of incineration is recognized as a renewable source of energy and is playing an increasingly important role in MSW management in Libya (Hamad et al., 2014).

Najjar et al. (2015) conducted a study to estimate the percentage of total plastic and PVC in particular, in solid household waste in the city of Tripoli, Libya. The results concluded that the weight percentages of plastic waste and PVC were about 10.52% and 1.36%, respectively. The percentage of PVC from plastic waste was only 12.94% (Najjar et al., 2015). Babalola (2015) presented a multi-criteria decision analysis to evaluate different waste management options and their applicability in Japan. The results showed that anaerobic digestion should be chosen as the best food and biodegradable waste treatment option concerning resource recovery (Babalola, 2015).

A study was carried out by Moftah et al. (2016) to evaluate the generation, composition and density of household solid waste in Tripoli city, Libya. It was concluded that the total generation quantity, daily generation rate, total volume and density were in Tripoli city agreed with those for African and Arabic countries. The study showed that Tripoli suffers from insufficient MSW management and lack of sanitary landfills (Moftah et al., 2016). Jovanović et al. (2016) presented a method for selection an optimal waste management system in the city of Kragujevac, Serbia through an integrated application of the life cycle assessment method and MCDM methods. Six different waste management strategies for the territory of the city were formulated and eight parameters were selected (Jovanović et al., 2016).

Omran et al. (2018) conducted a study in the City of Al-Bayda, Libya dealing with solid waste management. The aim of the study was to investigate the major problems facing the city in dealing with SWM in terms of generation, collection, handling, transportation, recycling and disposal of MSW. The conclusion was, there were major factors impacting the decision-making and operational processes of MSW that include lack of resources and services that significantly affect the disposal of waste and inadequate number of waste collection containers. This makes the distance to these containers for many households excessive and thus leading to an increasing likelihood of dumping solid waste in open areas and roadsides (Omran et al., 2018).

By reviewing the previous studies specifically, the studies that dealt with SWM in Libya, it can be noted that, vast majority of them focused on the classification of solid waste management rather than the selection of the technology treatment. To fill this research gap, this paper examines the selection of the appropriate method for the solid waste treatment.

3. Variants of municipal waste management technology

Several types of recycling, energy recovery or waste neutralization technologies are used in a system of waste management. Each of them shows different technical and environmental characteristics.

3.1. Composting

Composting is a biological process in which the organic matter current in waste is converted into enriched inorganic nutrients. The manure obtained has high nitrogen, phosphorus, and potassium content. Composting is often described as nature's way of recycling is a key ingredient in organic farming. At the simplest level, the process of composting only requires making a heap of wetted organic material (leaves, food waste) and waiting for the materials to breakdown into humus like substance by undergoing biological decomposition after a period of weeks or months (Ladan, 2014). The quality of compost depends upon the waste being composted. There are a number of biological or compost related technologies. These are open windrow, vermi-composting, enclosed composting and fermentation (Thompson-Smeddle, 2011).

3.2. Anaerobic digestion

Anaerobic digestion (AD) is a naturally occurring biological process that uses microorganisms to break down organic material in the absence of oxygen. In other words, AD is a process that makes any organic waste can be biologically transformed into another form, in the absence of oxygen. The production of biogas and other energy-rich organic compounds is mainly produced from the degradation of organic waste by microbial organisms (Arshad et al., 2011). A series of metabolic reactions such as hydrolysis, acid genesis, acetogenesis and methanogenesis are involved in the process of anaerobic decomposition (Charles et al., 2009). Anaerobic digestion can be applicable for a wide range of material including municipal, agricultural and industrial wastes and plant residues (Chen et al., 2008).

3.3. Incineration

Incineration, or thermal oxidation is the process of oxidizing combustible materials by raising the temperature of the material above its auto-ignition point. The process is done in the presence of oxygen, and maintaining it at a high temperature for sufficient time to complete combustion to carbon dioxide and water (EPA-CICA, 2003). Any non-combustible materials (e.g. metals, glass, stones) remain as a solid, known as incinerator bottom ash that always contains a small amount of residual carbon (DEFRA, 2007). The efficiency of the combustion process is affected by the factors such as time, temperature, turbulence (for mixing) and the availability of oxygen. These factors provide the basic design parameters for volatile organic compounds oxidation systems (ICAC, 1999).

3.4. Landfilling

Landfilling is the ultimate disposal process for the SWM. The process is simply dumping the waste in trenches or cells with leveling and compacting by trash compactors to reduce the size and the thickness of the layers, and finally the waste is covered by soil (Aljaradin & Persson, 2014). The quantity of MSW for land disposal can be considerably reduced by setting up waste processing facilities and recycling the waste materials as much as possible.

4. Multi-criteria decision making

Multi-Attribute Decision Making (MADM) is the most well-known branch of decision making. MADM models deal with decision making problems under the presence of a number of decision criteria. This class of models is very often called multi-criteria decision making (or MCDM). According to many authors MCDM is divided into Multi-Objective Decision Making (or MODM) and Multi-Attribute Decision Making (or MADM) (Karami, 2011).

MODM is a mathematical programming problem with multiple objective functions. Whereas, the developing of MADM models is based on several alternatives according to some criteria are ranked and selected. Ranking and selecting will be made among decision alternatives described by some criteria through decision-maker knowledge and experience (Karami, 2011; Wang et al., 2005; Chatterjee et al., 2018; Pamučar et al., 2018a). MCDM is approach for finding the optimal alternative from all the feasible alternatives according to some criteria or attributes (Stević et al., 2017; Pamučar et al., 2018b).

5. Analytic Hierarchy Process

Analytical hierarchy process is a common MCDM method. It is developed by Saaty to provide a flexible and easily understood way of analysing complex problems (Saaty, 1979, 1990). According to Chai et al. (2013) it has been found that AHP method was used more than any other MCDM methods. It breaks a complex problem into hierarchy or levels, and then making comparisons between possible pairs in a matrix to give a weight for each factor and also a consistency ratio. The AHP utilises a tree structure in order to simplify complex decision-making problems resulting in simplified sub problems, which can easily be examined. The AHP method can be distinguished in four main steps:

- Creation of a tree structure, which comprises of one goal, the criteria, and alternative solutions.
- Evaluation of each alternative solution in relation to each criterion.
- Calculation of the weighting factor of the criteria with subjective evaluation using pairwise comparisons.
- Synthesis of the results of stages 2 and 3 so as to calculate the overall evaluation of each alternative regarding the degree of achievement of each goal. Figure 1 presents the tree structure for the four SWT systems.

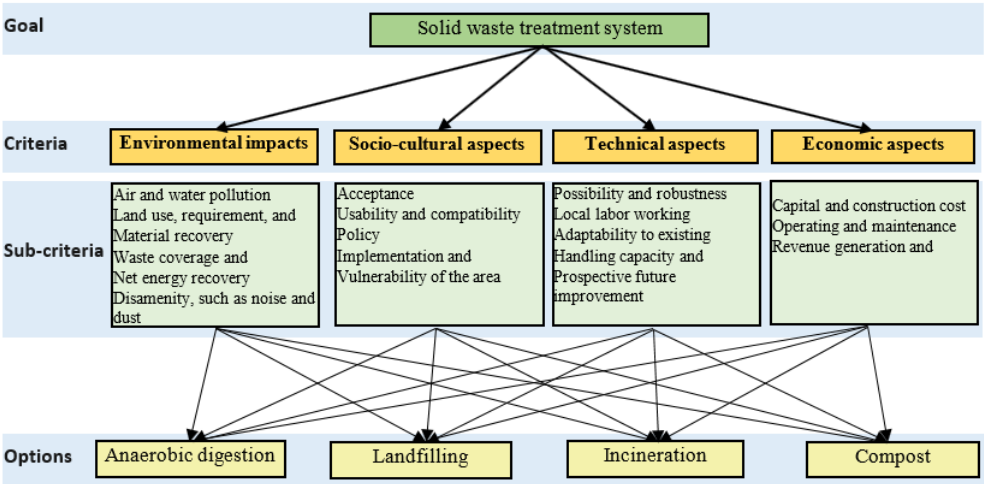

Figure 1. Tree structure for the four SWT systems

In the AHP method, pairwise comparisons permit the decision maker to concentrate only on one element at a time. Specifically, to explore how strongly important is one criterion related to another with regards to the goal?" The comparisons are the input into a matrix. If the matrix is sufficiently consistent, priorities can then be calculated with formula (1).

$$AW = \lambda_{\max} w \tag{1}$$

where A is the comparison matrix, λmax is the principal eigenvalue and W is the priority vector. The AHP model gives feedback to the decision maker on the consistency of the entered judgments through the measurement of consistency ratio (CR) by using formulas (2) and (3).

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

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{3}$$

where CI is the consistency index, n is the dimension of the comparison matrix, λmax is the principal eigenvalue and RI is the ratio index. The ratio index or Random Consistency index (RI) is given in Table 1. If the consistency ratio is less than 0.1 (<10%) the matrix is regarded as consistent, otherwise the matrix is inconsistent and it is suggested to modify the comparisons in order to reduce the inconsistency (Saaty, 1980). If all sub-priorities are available, they are aggregated with a weighted sum in order to obtain the overall priorities of the alternatives so as a final judgment can be made based on the ranking (Saaty, 1980; Saaty & Vargas, 2012).

Table 1. Random Consistency Index (RI)

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

6. Analysis of the results

The quantity of MSW generated in Libya is estimated at 3.2 million tons/year (Sawalem et al., 2009; Ali, 2014). The treatment of solid waste is done by throwing in open dumps designated by the relevant authorities and in many cases random dumps that are not controlled by the state. Lack of suitable facilities, inadequate management and technical skills, improper bin collection and shortages in solid waste plants are among the important issues resulting in poor collection and transportation of municipal solid wastes in Libya (Gebril et al., 2010). However, in Libya few MSW plants were established in several cities as shown in Figure 2. These plants are suffering from many obstacles, because all of them are outdated and need to be updated or replaced. For example, the MSW plant in Misurata, which was opened in 1982 with a capacity of 120 tons per day, currently the capacity is only 60 tons.

Figure 2. Distribution of solid waste plants in Libya

For the evaluation of the four treatment systems, with the use of the AHP, 12 cases were carried out. These cases were the base case, equally distributed criteria case, four cases of single-criterion analysis and six cases of multi-criteria analysis. In this paper, qualitative criteria are identified based on questionnaire forms that have been filled in by environmental experts and academic staff university members. Table 2 shows the pairwise comparison matrix of the general and organizational structure of the technology's sub-criteria. In order to facilitate the solution process for the AHP problem, Expert Choice software were used to compute the model.

Table 2. Criteria, sub-criteria and their weights

Criteria	Weight	CR	Sub-criteria	Weight
Environmental	0.581	0.07	Air and water pollution	0.286
			Land use, requirement, and contamination	0.046
			Material recovery	0.062
			Waste coverage and elimination	0.061
			Net energy recovery	0.077
			Disamenity, such as noise and dust	0.049
Socio-Cultural	0.204	0.07	Acceptance	0.119
			Usability and compatibility	0.027
			Policy	0.020
			Implementation and adoptability	0.023
			Vulnerability of the area	0.016
Technical	0.128	0.08	Possibility and robustness	0.054
			Local labor working experience	0.019
			Adaptability to existing systems	0.012
			Handling capacity and continuous process	0.031
			Prospective future improvement	0.012
Economical	0.086	0.08	Capital and construction cost	0.038
			Operating and maintenance cost	0.007
			Revenue generation and marketability	0.009
			Financial planning	0.011
			Employment and job creation	0.016
			Waste volume and composition	0.005

6.1. Base case

In the base case, the criteria weights have been calculated using pairwise comparison according to the AHP method. The following weighting factors are used: Environmental impacts 58%, socio-cultural aspects 20%, technical aspects 13% and economic aspects 9%. The weighting factors were given to each criterion. These percentages indicated that the environmental impact of each alternative option is the primary concern of this case, while socio-cultural aspects follow. Figure 3 presents the rating of alternative options for SWT system. As can be seen from Figure 2, the anaerobic digestion is the best option when a greater emphasis is given to environmental impact. Furthermore, compost and incineration are ranked second and third, respectively. On the contrary, landfill is ranked last.

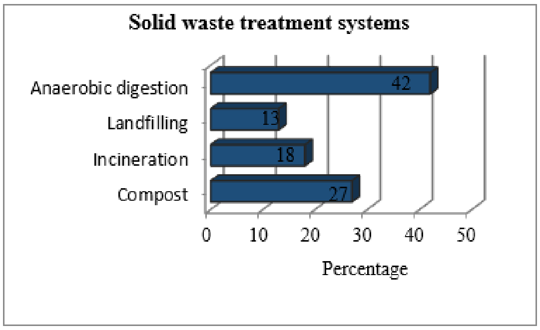

Figure 3. Overall evaluation of SWT system

The next step of the decision process of the AHP method is the sensitivity analysis, where the input data of criteria weighting are slightly modified in order to observe their impact on the results. If the ranking of treatment systems does not change significantly, the results are said to be robust. Bearing in mind that the opinions of experts may vary, a sensitivity study was carried out. The following cases were examined:

6.2. Equally distributed criteria (case 1)

In case1, the following weighting factors are used: Environmental impacts 25%, socio-cultural aspects 25%, technical aspects 25% and economic aspects 25%. Figure 4 presents the rating of alternative options for SWT system for this case. Again, the anaerobic digestion is the best option while landfill is ranked last.

6.3. Single-criterion analysis (cases 2–6)

In the single-criterion analysis (cases 2–6), the evaluation has been carried out with full emphasis to one criterion while the other four criteria are ignored.

6.3.1. Case 2

In case 2, the following weighting factors are used: Environmental impacts 100%, socio-cultural aspects 0%, technical aspects 0% and economic aspects 0%. As can be seen from Figure 5, the best option is the anaerobic digestion, landfill ranks last, given the fact that it has a high impact on the environment.

6.3.2. Case 3

In case 3, the following weighting factors are used: Environmental impacts 0%, socio-cultural aspects 100%, technical aspects 0% and economic aspects 0%. Figure 4 gives the overall ranking of SWT system when emphasis is given to socio-cultural aspects. The anaerobic digestion has the highest ranking while incineration receives the last position.

6.3.3. Case 4

In case 4, the following weighting factors are used: Environmental impacts 0%, socio-cultural aspects 0%, technical aspects 100% and economic aspects 0%. As can be seen from Figure 5, the compost has the highest-ranking while incineration receives the last position. This result was expected since the incineration system requires some technical consideration.

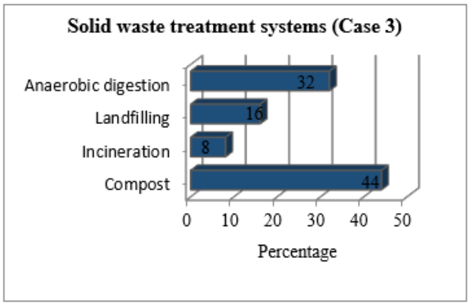

Figure 4. Overall evaluation of SWT system for case 3

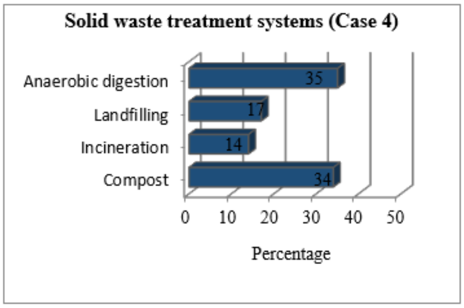

Figure 5. Overall evaluation of SWT system for case 4

6.3.4. Case 5

In case 5, the weighting factors used are: Environmental impacts 0%, socio-cultural aspects 0%, technical aspects 0% and economic aspects 100%. As shown in Figure 6, again the anaerobic digestion has the highest-ranking while the landfilling system receives the last position.

6.4. Multi-criteria analysis (cases 6–11)

According to multi-criteria analysis (cases 6–14), the evaluation of the four-selected SWT system has been carried out by giving greater emphasis (a larger weighting factor) to one criterion without ignoring the rest as was carried out in the single-criterion analysis (cases 6–9). In the last two cases, greater emphasis is given to two criteria at the same time (cases 10–11).

6.4.1. Case 6

In case 6, the following weighting factors are used: Environmental impacts70%, socio-cultural aspects 10%, technical aspects 10% and economic aspects 10%. As can be seen from Figure 7, the best SWT system is the anaerobic digestion while landfilling system receives the last position.

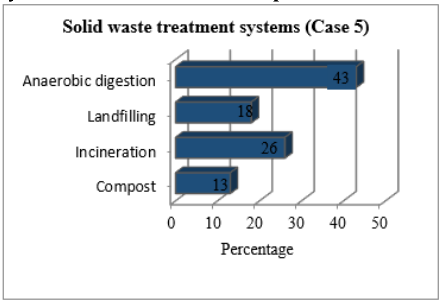

Figure 6. Overall evaluation of SWT system for case 5

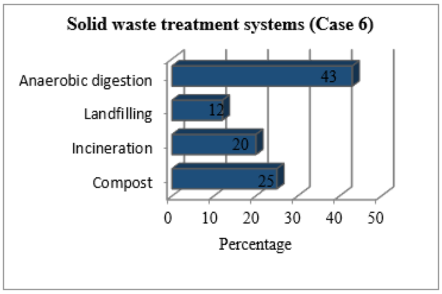

Figure 7. Overall evaluation of SWT system for case 6

6.4.2. Case 7

In case 7, the following weighting factors are used: Environmental impacts 10%, socio-cultural aspects 70%, technical aspects 10% and economic aspects 10%. Figure 8 presents the rating of alternative options for SWT system for case 7. According to this figure, the best waste treatment system is anaerobic digestion and next is compost while incineration receives the last position.

6.4.3. Case 8

In case 8, the following weighting factors are used: Environmental impacts 10%, socio-cultural aspects 10%, technical aspects 70% and economic aspects 10%. According to Figure 9, the best waste treatment system in case 8 is anaerobic digestion, and next is compost while incineration receives the last position. These outcomes are very similar to the results obtained in case 7.

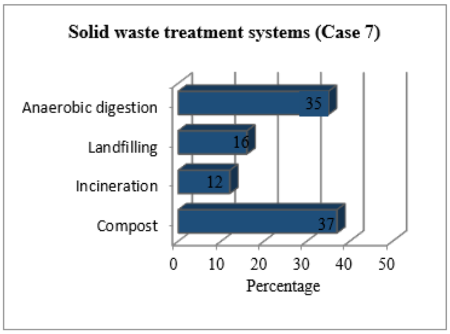

Figure 8. Overall evaluation of SWT system for case 7

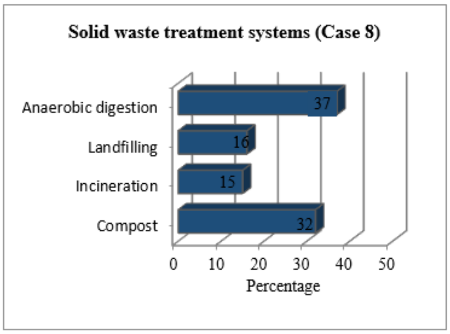

Figure 9. Overall evaluation of SWT system for case 8.

6.4.4. Case 9

In case 9, the following weighting factors are used: Environmental impacts 10%, socio-cultural aspects 10%, technical aspects 10% and economic aspects70%. As can be seen from Figure 10, the best SWT system is the anaerobic digestion while incineration system receives the last position.

6.4.5. Case 10

In case 10, the following weighting factors are used: Environmental impacts 35%, socio-cultural aspects 35%, technical aspects 15% and economic aspects 15%. As can be seen from Figure 11, the best SWT system is the anaerobic digestion while incineration system receives the last position.

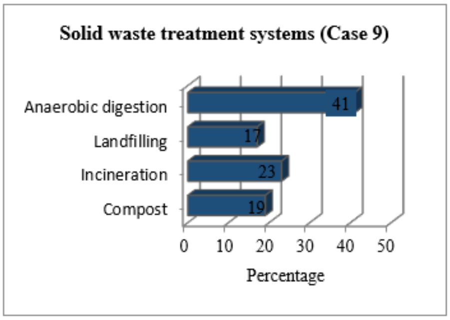

Figure 10. Overall evaluation of SWT SWT system for case 9

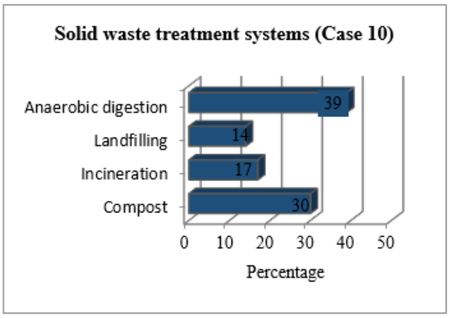

Figure 11. Overall evaluation of system for case 10

6.4.6. Case 11

In case 11, the following weighting factors are used: Environmental impacts 35%, socio-cultural aspects 15%, technical aspects15% and economic aspects 35%. As can be seen from Figure 12, the best SWT system is the anaerobic digestion while landfilling system receives the last position.

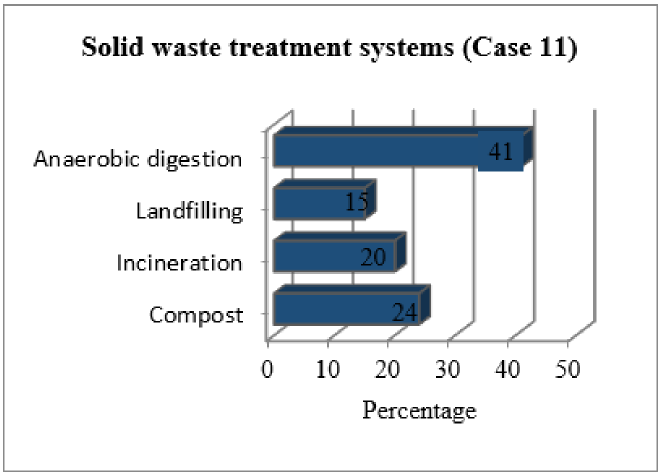

Figure 12. Overall evaluation of SWT system for case 11

Table 3 presents the criteria weights for the 12 scenarios conducted to the case study which is described above, and Table 4 summarises an overall evaluation and ranking of the four SWT systems under examination. The evaluation of the SWT systems was carried out using the AHP for 12 cases. These consisted of the base case, the equally distributed criteria, four cases of single-criterion analysis and six cases of multi-criteria analysis. Each treatment system presents a solution for the solid waste management system with a certain degree of trade-off between benefit and its consequences related to environmental, social, technical and economic issues. Sensitivity analysis is conducted to evaluate the robustness of the selected treatment options. A "What if Analysis" Figure 13 was performed to see if there were any changes among the selected treatment options. The results display no changes in the ranked results, as the anaerobic alternative remained the most suitable option for the treatment of the SWM. As can be seen from Figure 13, the majority of cases, the anaerobic digestion is considered to be better than the other systems (Landfilling, Incineration, and Compost) and is higher in ranking. On the contrary, the landfilling and incineration systems rank last in most of the cases. More specifically, in most of the cases (10 out of 12), the first in ranking SWT system is considered to be the anaerobic digestion and the worst (7 out of 12) is Landfilling. There is a need for improvement in the design of this treatment system, site location, size and management of the disposal sites. Existing practices must be improved immediately as they create environmental problems. It should be noted that the rank of SWT systems can be changed according to the future system development.

Table 3. Overall criteria weights for each scenario.

Criteria	Criteria Weights for each case (%)											
	Base Case	Case #01	Case #02	Case #03	Case #04	Case #05	Case #06	Case #07	Case #08	Case #09	Case #10	Case #11
Environmental impacts	58%	25%	100%	00%	00%	00%	70%	10%	10%	10%	35%	35%
Socio-cultural aspects	20%	25%	00%	100%	00%	00%	10%	70%	10%	10%	35%	15%
Technical aspects	13%	25%	00%	00%	100%	00%	10%	10%	70%	10%	15%	15%
Economic aspects	09%	25%	00%	00%	00%	100%	10%	10%	10%	70%	15%	35%

Table 4. Overall evaluation and ranking SWT system for each case

Solid waste treatment system	Base Case		Case #01		Case #02		Case #03		Case #04		Case #05	
	Score (%)	Rank	Score (%)	Rank	Score (%)	Rank	Score (%)	Rank	Score (%)	Rank	Score (%)	Rank
Anaerobic digestion	42%	1	39.7%	1	46.2%	1	39.1%	1	34.7%	2	38.4%	1
Landfilling	13%	4	15.7%	4	9.9%	4	16.5%	3	17.0%	3	19.3%	4
Incineration	18%	3	16.2%	3	21.7%	3	8.8%	4	13.5%	4	20.9%	3
Compost	27%	2	28.5%	2	22.2%	2	35.7%	2	34.8%	1	20.4%	2
	Case #06		Case #07		Case #08		Case #09		Case #010		Case #011	
Solid waste treatment system	Score (%)	Rank	Score (%)	Rank	Score (%)	Rank	Score (%)	Rank	Score (%)	Rank	Score (%)	Rank
Anaerobic digestion	43.6%	1	37.7%	1	35.2%	1	37.2%	1	38.9%	1	38.8%	1
Landfilling	12.2%	4	17.2%	3	17.5%	3	18.9%	3	15.9%	3	16.5%	4
Incineration	19.5%	3	10.6%	4	13.4%	4	17.9%	4	14.5%	4	17.0%	3
Compost	24.7%	2	34.5%	2	33.9%	2	26.0%	2	30.7%	2	27.7%	2

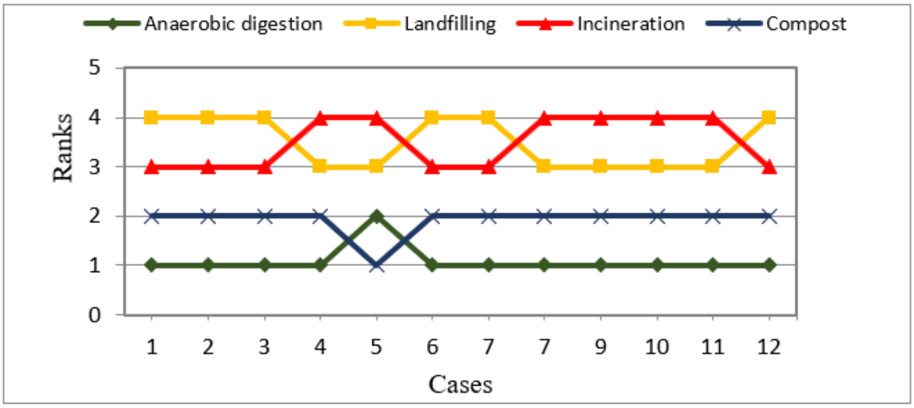

Figure 13. Sensitivity analysis for the 12 cases of the SWM

We feel the proposed method plays an important role in ranking of waste treatment systems, especially when it is in a situation where dynamic, and complex real-world problems. One of the most important advantages of the proposed approach is that it is based on a pair-wise comparison. Moreover, the method computes the inconsistency index, which is used to determine whether a respondent answered similar items in a consistent manner.

7. Conclusion

Undoubtedly, the waste treatment system in Libya is very poor, for instance, more than 97% of the waste is dumped in uncontrolled open areas. As a result, Libyan authorities need to take urgent steps in order to address the current situation. In this study, the multi-criteria decision-making approach is identified as a useful means for an integrated evaluation of the appropriate treatment options for the SWM. The methodology presented here can be used as a well-organized, strategic decision supporting tool for decision makers, politicians, and planners. It is essential to have consistent goals and objective information about the evaluation process of anaerobic digestion suitability for solid waste treatment based on environmental, sociocultural, technical, and economic aspects. Clearly, the anaerobic digestion and composting treatment systems are the two most preferred alternatives. Furthermore, a large part of the used fertilizer in the agriculture is imported from abroad, and most of the local fertilizer industries are not competitive in the today market. Also, the results show that the incineration alternative is in the last order, due to the inability to compete with current power generation methods in the country (e, g. Power generation using fuel oil and natural gas). Furthermore, Libya is also considered as rich country with renewable energy resources such as solar and wind energy. However, waste incineration is not a competitive alternative renewable energy. The performance of the treatment options based on the criteria mentioned earlier is a robust one similar to the synthesis results.

As anaerobic digestion is based on a naturally occurring biological process which produces biogas through anaerobic digestion, this can lead to reduce the main environmental problems of increasing organic waste production and increasing carbon dioxide in the atmosphere. Moreover, investments in this waste management facility can be considered to offer another source of revenue generation for waste management practitioners. Consequently, they facilitate and at the same time lighten the burden of waste management incurred by the municipal government. Anaerobic digestion technology has tremendous application in the future for sustainability of both environment and agriculture, with the production of energy as an extra benefit.

As the municipal governments do not have adequate options to dispose their waste, it is suggested that the proposed project must be implemented within a period of two to three years. It is needed that local authority's search for potential investors, with technical advice and support from international organizations in this aspect, to achieve this feasible project.

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