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Evaluation of waste management options using rapid impact assessment matrix and Iranian Leopold matrix in Birjand, Iran

S. Valizadeh[1] · H. Hakimian[2]

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Abstract
Population growth and the corresponding production of more waste as well as considering the lack of appropriate municipal solid waste management strategies in recent years have confronted the city of Birjand with huge waste disposal problem. This study evaluated different waste management options in Birjand, including open dumping, sanitary landfill, composting and recycling. Environmental impact assessment of these options was performed using two methods: rapid impact assessment matrix and Iranian Leopold matrix (modified Leopold matrix). The rapid impact assessment matrix method provides fast and accurate ways of analysis and reanalysis of specified components. Iranian Leopold matrix chiefly is used for the reorganization of the project impacts in both the building and operation stages. Composting option, with final scores of −0.5 and −2.34, respectively, in rapid impact assessment matrix and Iranian Leopold Matrix, had the least negative environmental impact. Also, as a result of both methods, open dumping had the most negative environmental impact. The result of sustainability determination for four alternatives showed that the composting, with *S*-Value equal 0.01 and −0.162, respectively, in rapid impact assessment matrix and Iranian Leopold matrix, is more sustainable than the other options. Therefore, composting option was introduced as first priority and the most logical strategy for municipal solid waste management in Birjand. Unfortunately, open dumping is currently the most common method of waste management in this city.

Keywords Composting · Environmental impact assessment · Landfill · Municipal solid waste · Recycling · Sustainability

Introduction

One of the most important issues of waste management in developing countries is finding a suitable method to disposal municipal solid wastes (MSW) (Sehker and Beukering 1998). The increasing amount of waste produced by urbanization in these countries is usually not well managed. Due to the high cost of waste collection systems, particularly in the collection and transportation to the landfill as well as low-skilled labor and allocation of low financial resources, the waste management system in developing countries has to face many problems (Moghadam et al. 2009). MSW management options are causing many environmental impacts such as climate change impacts and health effects attributable to air pollutants with emission of NO_x, SO_2, ozone-depleting substances, dioxins and fine particles and as well as depletion of non-renewable resources, contamination of water bodies, noise, accidents and effects on socioeconomic aspects (Smith et al. 2001).

In developed countries, due to extensive facilities and strict technical regulations concerning waste management, advanced disposal methods have been proposed, but in the developing countries, there are not appropriate strategies. Therefore, we should be looking for the appropriate environmental impact assessment (EIA) methods to identify the best MSW management alternatives which have the least negative impact on the public health risk and our environment.

Due to the increase of population in the recent years, the production of MSW has increased significantly in the city of Birjand (which located in the east of Iran). In addition, waste

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✉ S. Valizadeh
Valizadehsoheyl@yahoo.com

[1] Environmental Pollution, Tarbiat Modares University, Tehran, Iran

[2] Environmental Assessment and Landuse Planing, University of Birjand, Birjand, Iran

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produced in rural areas of around the city are also collected and transported to the landfill of Birjand. Currently, the most common methods of MSW management in Birjand are open dumping and incineration and due to many negative effects on the surrounding environment, it is necessary to explore different options to determinate the most appropriate MSW management option in this city.

There are variety of methods available to predict and mitigate the effects of different projects, including mapping, environmental hazard assessment, life cycle assessment, EIA, multiagent systems, linear programming and farming biological indicators (Muntean et al. 2007). There are several tools and techniques for EIA including modeling, matrices, checklists and decision-support system (Kuitunen et al. 2008).

EIA is a system which is used in assessing and evaluating the project impacts on the environmental component including physical, biological, sociological–economic and cultural, which can be due to the implementation of projects or programs (Gilbuena et al. 2013). The EIA evaluated environmental and social impacts of proposed projects by project managers with regard to the environment and interest groups. In general, the effects of project implementation on the environment are determined, and so is planned the measures to reduce these impacts (Ijäs et al. 2010).

In this study, two common methods were applied to EIA of MSW options, which include: rapid impact assessment matrix (RIAM) and Iranian Leopold matrix. The matrix methods integrate project activities into a checklist of environmental components. Then identify the interactions between different project activities and environmental components (Gholamalifard et al. 2014).

Pastakia and Jensen (1998), defined RIAM as a tool to organize, analyze and present the results of a holistic EIA. The RIAM model is used to compare different projects, based on their harmful and beneficial effects (Kuitunen et al. 2008). Also, this method proved to be an appropriate and recommendable method for the small-scale assessment and prioritizing of proposed projects (Shakib Manesh et al. 2014). The scales in RIAM allow assessment of both quantitative and qualitative data (Pastakia and Jensen 1998).

In this method, a matrix formed consists of project activities against environmental components. To evaluate the effects of these activities on the environmental component, a score is determined according to the expert opinions that specify the amount of expected effects on the components. Thus, this method is a flexible and very useful tool in EIA process. The main advantage of RIAM is integration of all the components and parameters into one platform, which is ensuring the rapid and transparent evaluation of more important impacts (Araújo et al. 2005). The main problem of this approach is the lack of reasons for judgment that remain locked behind a stated value, meaning that the assessment will be expressed only in the form of a number. Thus the determination of the reasoning behind the judgment is inconceivable without access to assessor. This personal judgment and taste as well as lack of transparency are one of the limitations of this approach (Pastakia and Jensen 1998).

The Leopold matrix method was developed by (Leopold 1971) and mainly was used to reorganization the project impacts. The Leopold matrix method was first introduced by Leopold in 1971. The Leopold matrix was later modified by Makhdoum (1982), due to the native condition of Iran, and was evaluated as the Iranian Leopold matrix used by Iranian experts matrix (Aghnoum et al. 2014). Among the matrix-based methods, the Iranian Leopold matrix is considered as one of the most commonly used methods for assessing environmental impacts in our country because of considering the effects of the project on both the building and operation stages and the implementation of the environmental components, and as well as due to its main method, has been modified and localized according to the conditions of different types of projects in Iran. In the formation of the matrix, all of the impressive activities on the environmental components must be considered as well as their potential to influence. In Leopold matrix, the columns and rows, respectively, belong to project activity (for example, flow alteration) and environmental components (for example, water temperature). Provide a checklist of factors which need to be considered in the EIA is the major benefit of Leopold matrix. As well as in this method, the EIA will be evaluated in both the building and operation stage of projects. Iranian researchers commonly use matrix methods in EIA process, because of the time and cost limitation (Mahiny et al. 2009). Additionally, research has verified the efficiency of the Iranian version of Leopold matrix. (Aghnoum et al. 2014). However, this matrix has several disadvantages. For example, in the scoring system, only the immediate effects have been considered and spatial and temporal variations have been neglected. In addition, synergistic relation effects are not considered. Also, this method requires a lot of information about the environmental components and the project activities. In addition, similar to the RIAM model, assessment is done by the expert's judgment which involves the different tastes and views in evaluation process (Lohani et al. 1997).

El-Naqa (2005) in Jordan and Aghnoum et al. (2014) in Mashhad, Iran, was examined the waste management options by using RIAM method, and sanitary landfill was introduced as a priority landfill option. As well as Mondal and Dasgupta (2010) apply the RIAM method for EIA of MSW site in Varanasi and concluded that sanitary landfill is the most appropriate option. Panahandeh et al. (2013) evaluated the environmental impact assessment of "implementation" composting option versus option "no implementation" by using the Leopold Matrix. In general, the "implementation" option with an average of + 2.17 versus "no implementation" option with an average of −8.13 had a perfect advantage and the plan was recommended by considering improvement suggests and corrective actions. Mirzayi et al. (2010) used from Iranian Leopold matrix method to evaluate the environmental impact assessment of the compost factory in Sanandaj, and some solutions were presented.

The purpose of the present study was to compare the feasibility of waste management options in the city of Birjand. These options included open dumping, sanitary landfill, composting and recycling. Which employ two common methods: RIAM and Iranian Leopold matrix. Thus, RIAM Reporter 3.1 and Excel 2010 were used to perform these methods. As well as, amount of sustainability was calculated for different options in this both methods, in order to evaluate whether the determined options could be considered as sustainable or unsustainable. The innovation of this study was to calculate of the sustainability in the Iranian Leopold matrix and its comparison with the sustainability that calculated in the RIAM method. In other words, the sustainability in the Iranian Leopold matrix was not calculated in another study so far. Finally, using the results of RIAM and Iranian Leopold matrix methods and compare them with the sustainability calculated in both methods, was determined the best MSW option in the city of Birjand. This study was conducted in 2016 in the city of Birjand, South Khorasan Province.

Materials and methods

Scene setting

The city of Birjand is located in South Khorasan Province that is the most populous city in this province with a population of 221,756 people, according to the census in the year of 2006. This city has a semi-desert climate. There is no permanent river and stream, but there are only few seasonal rivers in the city.

Description of landfill

The landfill of Birjand is located on the eastern side of the dirt road of Birjand-Shoshod, which is about 5 km away from Birjand. The wastes of the city and its suburbs are collected and disposed in this location. The landfill location of this city is shown in Fig. 1.

Current environmental issues

Several factors were considered to select the suitable MSW management option in the city of Birjand, including transportation of waste materials in the shortest distance and time, public acceptability, environmental impacts, suitable climatic, topography, hydro-biological, hydro-geological

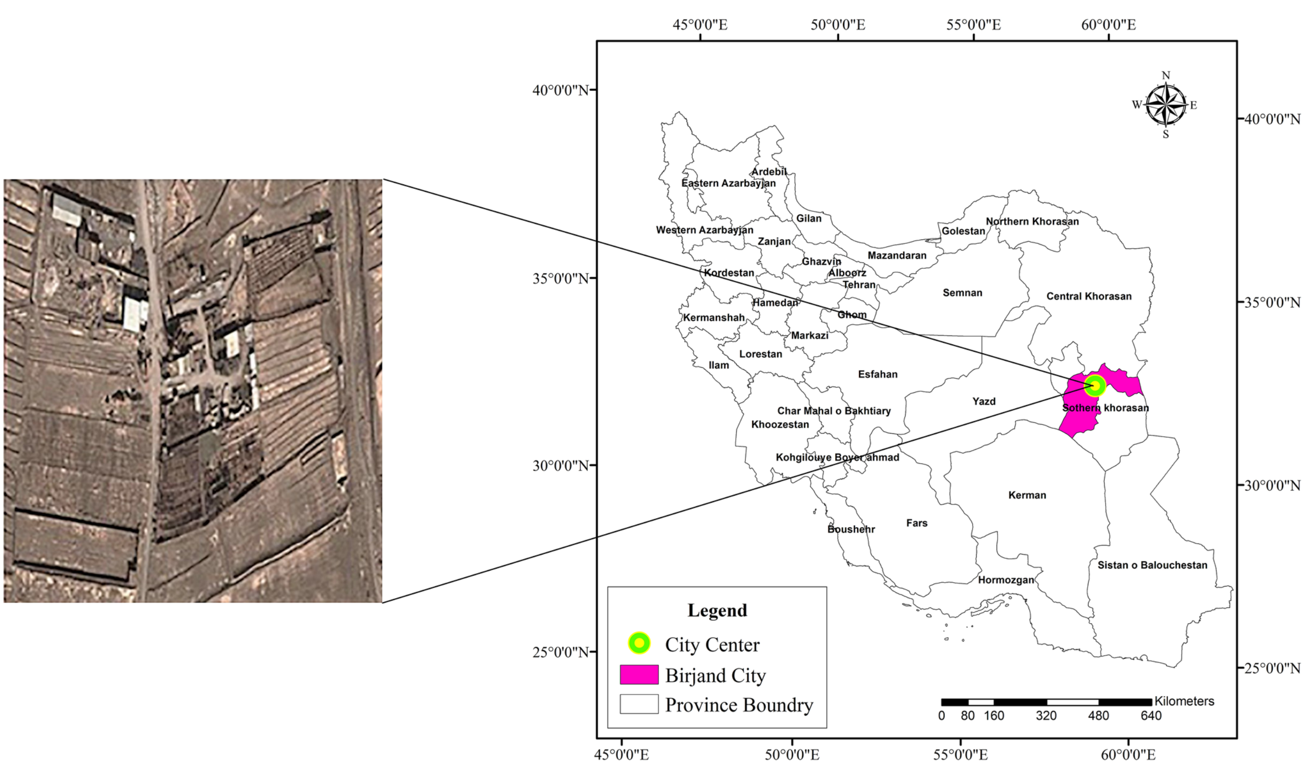

Fig. 1 Location map of landfill, Birjand, Iran

conditions, proximity to residential areas, rebuilding costs, landfill drainage, seismic and flood determination, local public health and compliance with landuse planning.

Project alternatives for landfill of Birjand

In both methods, i.e., RIAM and the Iranian Leopold matrix, four alternatives were considered as MSW options in the city of Birjand, including open dumping, sanitary landfill, recycling and composting.

In the Asian countries, the much of the MSW, excreted in open waste dumping sites without suitable measures (Eguchi et al. 2013). Currently, the open dumping without proper coverage is the most commonly used option for MSW management in Birjand; therefore, a large amount of waste disposal is burned under non-controlled condition (Watanabe et al. 2005). This has caused several adverse environmental consequences, including bad odors, dangerous diseases and infectious waste, leachate intrusion into groundwater aquifers, chemical and physical changes in soil, accumulation of disease-carrying animals and vermin, and many cultural and social problems. Therefore, increased health risks to local communities.

Sanitary landfill is a safe method of waste disposal to prevent from exposure of waste and its derivatives to the living environment and soil (Taheri et al 2014). Sanitary landfill limited the exposure of the environment and human to the adverse effects of solid wastes placed on the soil. This method reduces the negative effects of waste disposal, because using the appropriate and impervious coverage prevents the release of landfill gas and leachate and also limited the access of vectors (Sorg and Hickman 1968), odors and the accumulation of harmful animals. The appropriate covers are designed in several layers with proper materials and suitable size and thickness to prevent any harmful emissions from the landfill.

Composting is an appropriate process for the conversion organic waste to a product which used for soil fertility (Shen et al. 2015). In ecosystems, compost is beneficial for stream reclamation and increased water-holding capacity of the soil, wetland construction, erosion control, and as landfill cover (Soumare et al. 2003).

In fact, recycling is a process that prevents the loss of useful waste. Recycling represents a prominent indicator of environmental sustainability that showed links between waste materials and landfilling in terms of economic costs, health and environmental risks. Due to resource decreases and wastes increase that has occurred recently, recycling has thus become imperative and a critical environmental practice (Crociata et al. 2015). Recyclable material mainly is including plastics, glass, paper, textiles and waste electrical and electronic equipment (Smith et al. 2001).

RIAM method

RIAM concept and basics

The RIAM method evaluated the effects of project activities on the environmental components, thus a score determined for each activity against each component. In RIAM, the assessment criteria divided into two groups: (A) Criteria that are of importance of condition, which can change independently obtained score. (B) Criteria that are of value to the situation, but cannot change independently obtained score. In the scoring process, the scores of each criterion in group (A) multiplied. The use of multiplication for group (A) can be considered the weight of each score individually, whereas the weighted sum of the scores provides the same conclusion for various conditions, which indicates that the individual value scores alone do not effect on the overall score; therefore, the collective influence of all scores in groups (B) is generally considered into account. Based on RIAM method, the final Environment score (ES) can be expressed as (Pastakia and Jensen 1998).

$$\left(A_1\right) \times \left(A_2\right) = \text{AT} \tag{1}$$

$$\left(B_1\right) + \left(B_2\right) + \left(B_3\right) = \text{BT} \tag{2}$$

$$(AT) \times (BT) = \text{ES} \tag{3}$$

where (A_1) and (A_2) are the criteria scores for group (A). Also, (B_1), (B_2) and (B_3) are the criteria scores for group (B); and so (ES) is the environmental score for each option.

Assessment criteria

The impacts evaluation of each option on environmental components was performed based on criteria and scales that presented in Table 1 (Pastakia and Jensen 1998).

Environmental components

In the RIAM method, environmental components are located in four categories which are expressed as follows: physical/chemical (PC), biological/ecological (BE), sociological/cultural (SC) and economical/operational (EO). A total of 38 environmental components were used to evaluate the project alternative for the landfill management of Birjand. The components included thirteen PC, eleven BE, seven SC and eleven EO environmental components. The descriptions of the used components are provided in Table 2.

Table 1 Assessment Criteria in RIAM analysis

Criteria	Scale	Description
A_1: importance of condition	4	Important to national/international interests
	3	Important to regional/national interests
	2	Important to areas immediately outside the local condition condition
	1	Important only to the local condition
	0	No importance
A_2: magnitude of change/effect	+ 3	Major positive benefit
	+ 2	Significant improvement in status quo
	+ 1	Improvement in status quo
	0	No change/status quo
	− 1	Negative change in status quo
	− 2	Significant negative disbenefit or change
	− 3	Major disbenefit or change
B_1: permanence	1	No change/not applicable
	2	Temporary
	3	Permanent
B_2: reversibility	1	No change/not applicable
	2	Reversible
	3	Irreversible
B_3: cumulative	1	No change/not applicable
	2	Non-cumulative/single
	3	Cumulative/synergistic

Environmental assessment using RIAM

In order to use the evaluation process, a matrix was formed for each option, components were defined, and individual criteria scores were set down within each cell. In fact, four options include open dumping, recycling, composting and sanitary landfill, were saved in the program. There are 38 factors that are influenced by environmental impact assessment. These factors are categorized into four main groups: PC, BE, SC and EO environmental component. Each of these factors was assigned a code. In the scoring process, at first, each environmental component was awarded the scores for A_1, A_2, B_1, B_2 and B_3 by using an average of experts opinion by considering investigation the environmental effects of each alternative. Thus with regard to Eqs. (1–3), the ES is calculated for each environmental component (10 PC, 7 BE, 10 SC and 11 EO components). Then, these ES were multiplied by the contractual scores that expressed in Table 3. Finally, the sum of calculated values in the past step divided by the total number of factors (38 factors) and was introduced as the overall ES for comparing of four MSW alternatives in the Birjand. Therefore, according to the final score, the alternative with the least environmental impact was identified and proposed as the most appropriate MSW options in the Birjand.

Results can be graphically presented in histograms that provide comparisons of the harmful and beneficial effects of the alternatives, so to identify important negative components (El-Naqa 2005).

Iranian Leopold matrix

Iranian Leopold matrix investigates the relation among project activities and environmental components that proposed by Leopold (1971) (Aghnoum et al. 2014). In this study, the Iranian Leopold matrix (modified Leopold matrix) was used to assess the environmental impacts. This matrix contains all project activities in the building and operational phases (shown in Table 4) in columns and various environmental components such as physical, biological, economic and social (are given in Table 5) in rows (Gholamalifard et al. 2014).

Also, each environmental activity can be evaluated in terms of impact intensity and domain impact. In the method expressed by Leopold (1971), the scoring system for evaluation of project impacts on the environmental components is in the range of 10 to − 10. This classification is very understandable for English speakers, but in Persian language this is very difficult or probably impossible (Narimisa et al. 2013). Therefore, a new classification offered by Makhdoum as Iranian Leopold matrix with a range of − 5 to 5 is appropriate for use in Iran (Gholamalifard et al. 2014). The influence of an interaction between a project activity and an

Table 2 Environmental components for the RIAM analysis

Component designation	Component description
PC1	Air pollution and greenhouse gases emissions and other toxic gases
PC2	Surface water pollutions
PC3	Leachate and groundwater contamination
PC4	Noise pollution and annoying noises
PC5	Dust
PC6	Odor emissions
PC7	Hazardous wastes entering the environment
PC8	Soil instability and erosion
PC9	Topography and land shape
PC10	Changing in microclimate
BE1	Fertility and soil quality
BE2	Vegetation
BE3	Animal population
BE4	Biodiversity
BE5	Wildlife
BE6	Lifecycle
BE7	Plant and animal habitats
SC1	Esthetic
SC2	Communities living near landfill
SC3	Public health
SC4	Public acceptance
SC5	Development and housing projects near landfill
SC6	Density and population growth
SC7	Tourism
SC8	Current landuses around Landfill
SC9	Unemployment and creating job opportunities in the region
SC10	Life quality of local peoples
EO1	Revenues of local communities from landfill activities
EO2	Costs involved during the process of dumping to private land
EO3	Costs of transferring waste to landfill
EO4	Costs of paying the workers' rights
EO5	Costs of administrative, operating and maintenance
EO6	Costs involved in recycling and reuse of municipal solid wastes
EO7	Costs involved in recycling and reuse of municipal solid wastes
EO8	Revenues from recycled and reused municipal solid waste
EO9	Costs for the collection of leachate
EO10	Costs for the composting
EO11	Revenues of composting

environmental component is described by the assignment of a numerical value from −5 to 5.

So with regard to the field visit of landfill and the use of an average of expert's opinion, in the Iranian Leopold matrix a score was assigned (in range of −5 to 5) to interaction of each specified activity against each environmental component. Except open dumping has only building stage, and other options have building and operation stages. Thus in these stages for each environmental component, including physical (P), biological (B), socioeconomic (SE) and cultural (C), a score determined which is average of initial scoring in the Iranian Leopold matrix. Then, for each stage, the average of four environmental components was calculated. In the end, the final score of each option calculated with sum of building and operation scores.

In summarizing the effects, means of positive and negative effects for each activity and each environmental factor were calculated, and the ranking was determined in the modified Leopold matrix. Table 6 classifies positive and negative effects that relate to the final scores of Iranian Leopold matrix.

Table 3 The range bands of environmental scores in RIAM analysis

Description of range bands	Range bands	Environmental score	Contractual scores
Major positive change/impacts	+E	+72 to +108	5
Significant positive change/impacts	+D	+36 to +71	4
Moderately positive change/impacts	+C	+19 to +35	3
Positive change/impacts	+B	+10 to +18	2
Slightly positive change/impacts	+A	+1 to +9	1
No change/status quo/not applicable	N	0	0
Slightly negative change/impacts	−A	−1 to −9	−1
Negative change/impacts	−B	−10 to −18	−2
Moderately negative change/impacts	−C	−19 to −35	−3
Significant negative change/impacts	−D	−36 to −71	−4
Major negative change/impacts	−E	−72 to −108	−5

In the next step, the mean positive scores indicate environmental acceptance of projects; for example, the mean rankings in the range of −3.1 to −5 indicate unacceptability of the project; also mean rankings between 5 and 4 indicate that the project needs to be performed with correction options improvements in design (Baby 2010).

To clarify the overall EIA process, the flowchart of EIA process using RIAM and Iranian Leopold matrix methods is expressed in Fig. 2.

Using questionnaire manner in RIAM and Iranian Leopold matrix analysis

In this study, it was decided to use the questionnaire manner to increase the accuracy of scoring process. Therefore, a list of 50 experts was prepared who are mainly local and familiar with the condition of study area and Birjand city. They include university professors (22 people), experts of waste management part in municipality of Birjand (10 people) and experts in Birjand landfill site (18 people). Then, the two matrices mentioned above were sent to the experts as a questionnaire form. The scoring methods in this matrix (as a guide to scoring), as presented in Table 1 and 6, were also submitted to them. It is considered that the authors' scoring was based on their expertise, field observations and recognition from the study area. Both matrices were completed by the authors. Therefore, using averaging manner, one final matrix was obtained from the views of professor, experts, and authors for each method. In conclusion, the average score given by the experts was used for the final scoring process as well as the information obtained from the field visit.

Sustainability

In the current research, developed model by Phillips and Mondal (2014) was used to evaluate the sustainability of a MSW options, which is based on the mathematical model of sustainability for an MSW disposal site in Birjand. The model was applied in order to evaluate whether the determined options could be considered as sustainable or unsustainable, and if it is sustainable, what is the level and quality of sustainability for the option(s) of waste disposal at the local level (Phillips 2013). This method employs several equations and their descriptions are presented in the following (Table 7).

Field visits have been done for better evaluation of the effects of each option on environmental components. To this purpose, current site of the city of Birjand was selected. Also, the landfill site of Mashhad City has been visited to investigate the options that did not exist in Birjand landfill site, such as composting and sanitary dumping. Above options being carried out with acceptable quality in Mashhad landfill site.

Results and discussion

Environmental impact assessment

RIAM method

The RIAM method considers various aspects of the implementation of four options, including the importance of condition, magnitude of change or effect, as well as permanence, reversibility and cumulative features of effects. RIAM

Table 4 Building and operation activities in Iranian Leopold matrix

Building	Operation
Activities	
Workshop mobilizing	Earthworks
Temporary camp	Construction niches
Recruitment workers	Maintenance of main and secondary roads
Soil taking and soil spill	Preserving green space and water
Fencing	Water supply
Construction of passages	Water convey
Construction of buildings	Water consumption
Construction of road	Employment
Drainages	Transport workers
Concrete works	Service contractors
Workers transport	Transport of raw materials
Building material securing	Transportation of goods
Building material transport	Repair shops
Installations transport	Power preparation
Securing electricity	Power supply
Electricity transmission	Fuel
Securing fuel	Fuel storage
Fuel transmission	Fuel consumption
Fuel reserve	Sanitation
Fuel expenses	Wastewater collection
Securing water	Waste
Water supply	Effluent channels
Water expenses	Wastewater storage
Creation of enclosure	Waste collection
Transport services	Waste disposal
Repair shop services	Recycling of waste
Depot of building material	Sports and recreation facilities
Construction of factory	Defect leakage and emission
Leachate repelling	Residential facilities and residential
Waste repelling	Public warehouses
Creation of Garden	Motor services
Pickup of factory	Fire Station

method examines the most effective factors and project activities, and unlike the Iranian Leopold Matrix, the scoring system is performed in one step and an aggregation of both building and operation stages. Therefore, the environmental impacts of each option were determined. The overall results indicated the composting is as the most appropriate MSW option in Birjand, and it has minimum environmental impact in comparison with the other alternatives.

RIAM analysis matrix for different impacts of open dumping on environmental components is clearly shown in Fig. 3 (open dumping). This option has enormous negative effects on SC and EO environments. It means that heavy metals and other pollutants in the waste washed by leachate and are directly exposed to soil and underground aquifers. On the other hand, waste without suitable coverage caused gases and volatile organic compounds and noxious greenhouse emissions into the surrounding environment, therefore causing many negative effects (Mondal and Dasgupta 2010).

According to Fig. 3 (Sanitary landfill), the results showed that the most negative effects and the most positive effects were observed on PC and SE environments, respectively. Also, the negative effects of sanitary landfill on EO components are mainly due to high enterprise, operational and maintenance expenses.

RIAM analysis matrix of composting is shown in Fig. 3 (Composting). The results showed that the most negative effects of these options occurred in the PC and SC environments and included negative impacts on tourism and esthetic appeal of the area, which were mainly due to the odors and emission of gases generated by the landfill. On the other hand, the development of residential areas around is limited. The greatest positive impact on the environment was observed in the EO and BE components, and it is economic benefits for locals and the government and contributes to soil fertility and biodiversity in the region (Nakasaki et al. 2015).

As shown in Fig. 3 (Recycling), the results of recycling were similar to composting, so that the most negative effects occurred in the PC and SC environments. These impacts were mainly due to the cost of collection, transportation and storage of different types of waste. The most positive effects were observed in EO section. Recycling has many positive effects, including preventing the dissipation of national wealth. The results of the RIAM analysis for all of options are presented in Fig. 3.

Table 8 indicates the summary scores of RIAM analysis matrix for each option. According to the obtained results, the final score was calculated for all options. The composting option had the lowest negative effects, with a final score of −0.5. Sanitary landfill and recycling came next, with final scores of −0.763, −1.184, respectively. And finally, open dumping had the most negative effects, with a final score of −2.211.

Iranian Leopold matrix

In this method, four options (open dumping, sanitary landfill, composting and recycling) were investigated. Building and operation phases of each option and their effects on the physical, biological, economic and social–cultural environments were examined. Table 9 summarizes the results of this matrix; according to Table 9 and Fig. 4, the composting option has lower negative effects than other investigated options. Also, recycling and sanitary landfill options come next, though the difference between these two options is insignificant. As suggested by the RIAM method, the open dumping, with regard to its negative

Table 5 Environmental factors in Iranian Leopold matrix

Physical	Biological	Socioeconomic	Cultural
Environments			
Micro climate	Aquatic ecosystems	Population	Social acceptance
Air quality	Land ecosystems	Emigration	Clans and tribes
Environment sound	Rare species of plant	Specialty	Health indicators
Regime of water	Rare species of animal	Resettlement	Education indicators
Regime of flood water	Migration of animals	Revenue and Expenses	Major diseases
Quality of surface water	Animal population	Employment and Unemployment	Drinking water quality and water supply
Quality of grand water	Habitats of animals	Equipment prices rise	Tourism
Water standing level	Plant habitats	Agriculture	Facilities and services
Expenses of surface water	Plant density	Mining and Industry	Educational Services
Expenses of grand water	Wood production	Services	Cultural characteristics
Coastal water	Behavioral patterns of animals	Transport	Monuments and religious buildings
River morphology	Place of reproductive animals	Traffic	Registered cultural heritage
Advance of salty water	Food chain	Welfare	No cultural heritage
Sedimentation	Diversity	Water consumption	Landscapes
Soil erosion	Carriers	Waste	
Soil particulars	Protected areas	Effluent	
Soil constancy		Leisure time	
Drainage		Safety and Security	
Land shape		Landuse	
Shuddering		Plans for future development	
Flood water plains		Sensitive applications	
Slip and expulsion			

Table 6 Classified of positive and negative effects in Iranian Leopold matrix

Ranking average	Positive Effects or consequences	Ranking average	Negative effects or consequences
4.1–5	Excellent or very good Positive consequences	− 4.1 to − 5	Negative consequences of destructive or very severe
3.1– 4	Good positive consequences	− 3.1 to − 4	Extreme, bad and destructive negative consequences
2.1–3	Moderate positive consequences	− 2.1 to − 3	Moderate negative consequences
1.1–2	Weak positive consequences	− 1.1 to − 2	Weak negative consequences
0–1	Slight positive consequences	0 to − 1	Slight negative consequences

effects on the operation phase, was recognized as the most inappropriate option with a final score of − 3.06.

The average negative effects of four options in different project phases are shown in Fig. 5, as can be seen, the open dumping despite the lack of building phase, has more negative effects than other options. As well as that represented the negative effects of a sanitary landfill, composting and recycling in the operation phase are less than building phase, which is due to more revenue and prevents energy loss resulting from the implementation of these three options in the operation phase.

MSW options

Open dumping

Open dumping can cause hazardous impacts for environment, humans and other organisms by chemical contaminations diffusion, thus lead to reduce the environmental quality and the public health level. These chemical contaminations mainly include hexabromocyclododecanes (HBCDs), brominated flame retardants (BFRs) and polybrominated diphenyl ethers (PBDEs) (Eguchi et al. 2013).

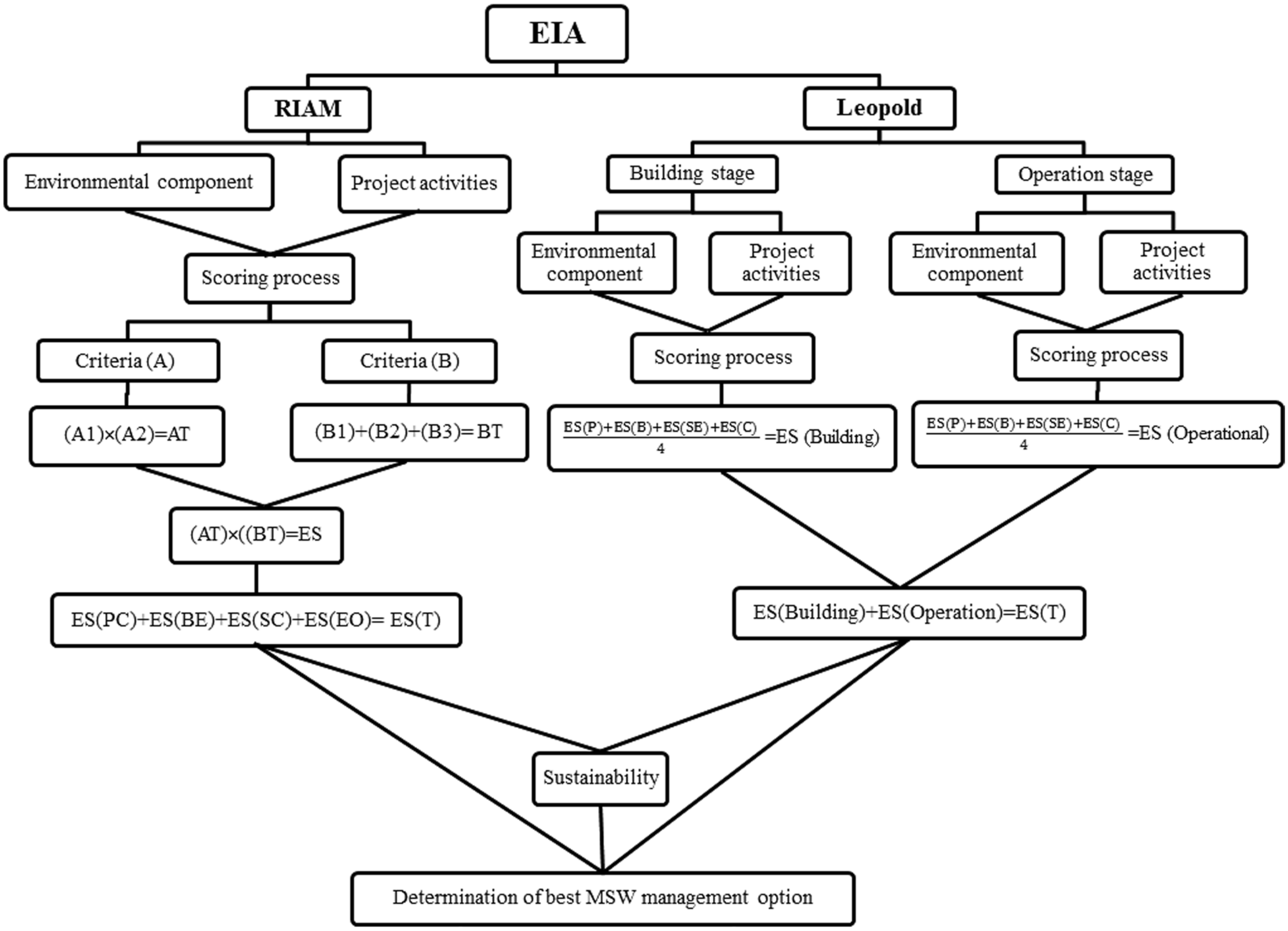

Fig. 2 Flowchart of EIA process

Table 7 Description of the applied equations in the model

Equation no.	Model equation	Description
(1)	$S(t) = E(t) - H_{NI}(t)$	Sustainability (S), time (t), value of the environment (E), human needs and interests (H_{NI})
(2)	$E(t) = \frac{\sum PC + \sum BE}{PC_{max} + BE max}$	
(3)	$H_{NI}(t) = \frac{(SC max - \sum SC) + (EO max + \sum EO)}{(SC max + EO max)}$	Socio logical-Cultural (SC), Economical-Operational (EO): H_{NI} is associate to the resources and facilities accessible and obtained by E, which certifies sustainable circumstances for human to live and survive
(4)	$E(t) > H_{NI}(t) \Leftrightarrow S(t) > 0$	If value of E is greater than H_{NI}, So infers sustainability
(5)	$E(t) \leq H_{NI}(t) \Leftrightarrow S(t) \leq 0$	If the E is less than or equal to the H_{NI}, thus sustainability would not occur and suggests unsustainability

Pollutants emitted from open dumping site also make the human exposure to dioxin-related compounds (DRCs) (Kunisue et al. 2004), and hexachlorocyclohexanes (HCHs) (Subramanian et al. 2007).

The PC1 component (air pollution and greenhouse gases emissions and other toxic gases) in the open dumping has more negative score (RB: -C, RV = −24) compared with other MSW options, because as mentioned above different pollutants and toxin gases due to the lack of appropriate coverage layers for the landfill are released easily to environment.

The annual rainfall average in Iran is 252 mm that is nearly 1/3 of the world's rainfall average; moreover, the evaporation average in Iran is three times more than the global evaporation average. The daily water consumption in Iran is 300 L, which is double the global consumption (150 L per day). The

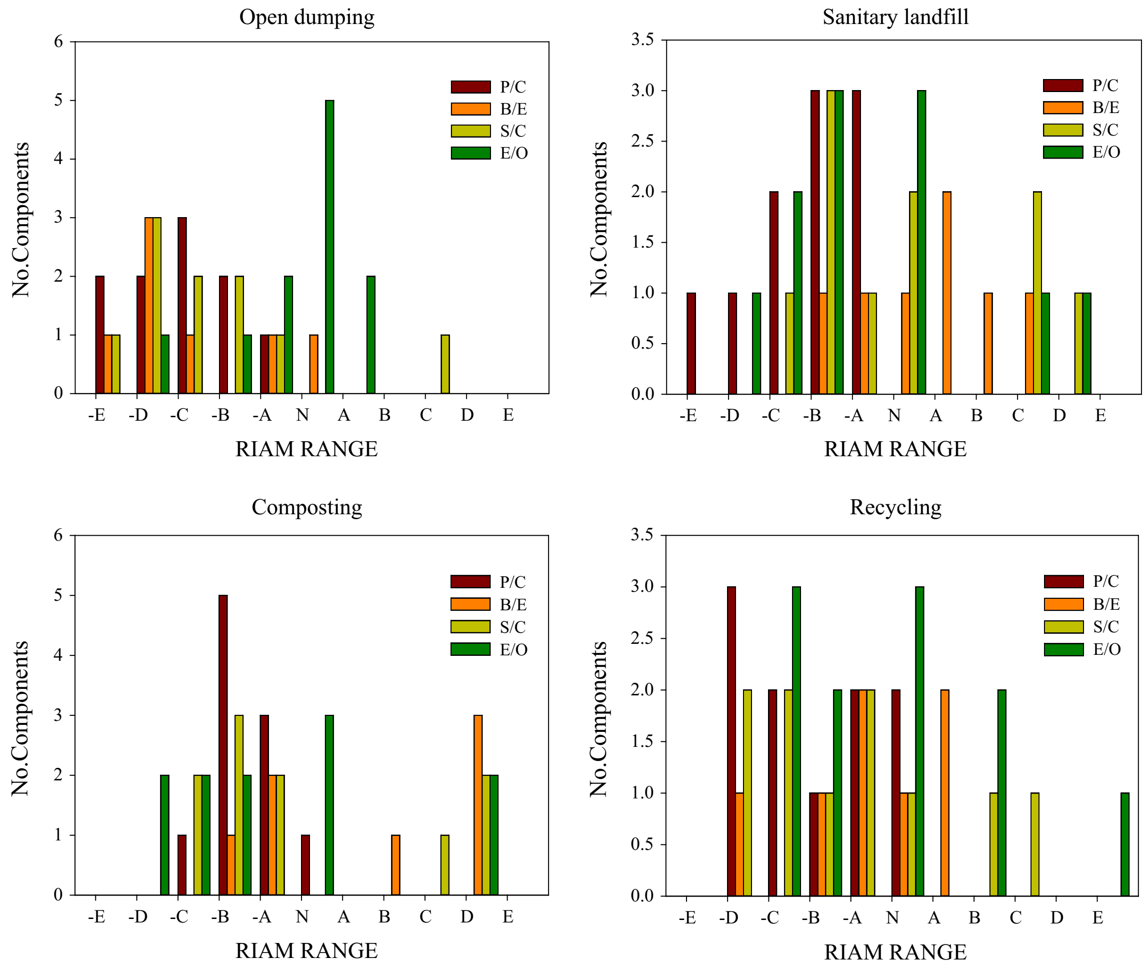

Fig. 3 RIAM analysis of Open dumping, Sanitary landfill, Composting, Recycling, *Y*-axis: number of component

annual rainfall average in the Birjand even is lower than average for the country (about 171 mm). Therefore, due to the hot and dry climate of Birjand, the surface and groundwater resources have a great importance. Lack of proper coverage in open dumping also makes the open dumping as the most dangerous option in case of surface water pollution (PC1) and groundwater contamination (PC2), with (RB: -D, RV = −36) and (RB: -E, RV = −81), respectively. Because the leachate from household, industrial and hospital wastes are now easily available for surface water resources.

Penetration leachate containing hazardous contaminants to soil structure changes the Physio-chemical characteristics of the soil and therefore the soil structure is destroyed. Because of providing a direct link between leachate and soil, the open dumping has the most negative impact on the soil instability and erosion (PC8), with RB: -A, and RV = −6.

Due to the presence of Birjand in hot and dry region, increasing the temperature causes many negative effects, including increase in evaporation and reduction of water resources level. It also creates many environmental problems for anthropogenic and animal environment. The continuous and unlimited release of greenhouse and toxic gases from open dumping sites increases the temperature, and so gradually changed the microclimate of the region. Therefore, open dumping has a greater role in the climate change than the other options (RB: -C, RV = −32).

The negative effects of open dumping in the EO components are less than the other options. This component is less expensive compared to other options because it is mainly referring to the MSW management costs, and also do not need to implement the construction phase and device and advanced equipment.

Sanitary landfill

Sanitary landfill, compared to option 1, declines the emission of non-CH_4 and CH_4 organic compounds and toxicants (such as toluene, vinyl chloride, benzene) into the surrounding environment. Avoiding gas emissions from landfill to the environment will be caused the declining fire risk and

Table 8 Summary scores of RIAM matrix method (options 1–4)

Class	− E	− D	− C	− B	− A	N	A	B	C	D	E
Average class (ES)	− 5	− 4	− 3	− 2	− 1	0	1	2	3	4	5
Option 1: open dumping											
PC	2	2	3	2	1	0	0	0	0	0	0
BE	1	3	1	0	1	1	0	0	0	0	0
SC	1	3	2	2	1	0	0	0	1	0	0
EO	0	1	0	1	2	5	2	0	0	0	0
Total	4	9	6	5	5	6	2	0	1	0	0
Final score	− 2.211										
Option 2: sanitary landfill											
PC	1	2	2	3	3	0	0	0	0	0	0
BE	0	0	0	1	1	1	2	2	1	0	0
SC	0	0	1	3	1	2	0	0	2	1	0
EO	0	1	2	3	0	3	0	0	1	1	0
Total	1	3	5	10	5	6	2	2	4	2	0
Final score	− 0.763										
Option 3: composting											
PC	0	0	1	5	3	1	0	0	0	0	0
BE	0	0	0	1	2	0	0	1	0	3	0
SC	0	0	2	3	2	0	0	0	1	2	0
EO	0	1	3	2	0	3	0	0	1	1	0
Total	0	1	6	11	7	4	0	1	2	6	0
Final score	− 0.500										
Option 4: recycling											
PC	0	3	2	1	2	2	0	0	0	0	0
BE	0	1	0	1	2	1	2	0	0	0	0
SC	0	2	2	1	2	1	0	1	1	0	0
EO	0	0	3	2	0	3	0	2	0	1	0
Total	0	6	7	5	6	7	2	3	1	1	0
Final score	− 1.184										

Table 9 Final score options in the modified Leopold method

Building phase						Operation phase					Total
Options	A_1	B_1	C_1	D_1	Final score (building)	A_2	B_2	C_2	D_2	Final score (operation)	Final score
Open dumping	–	–	–	–	0	− 3.07	− 3.07	− 2.74	− 3.35	− 3.06	− 3.06
Sanitary dumping	− 1.63	− 1.73	− 1.36	− 1.42	− 1.54	− 1.38	− 0.95	− 1.17	− 1.02	− 1.13	− 2.67
Composting	− 1.57	− 1.60	− 0.74	− 1.68	− 1.4	− 1.37	1.02	0.55	− 0.83	− 0. 94	− 2.34
Recycling	− 1.45	− 1.45	− 0.92	− 2.14	− 1.49	− 1.15	− 1.08	− 0.48	− 1.64	− 1.09	− 2.58

*A (Physical) B (Biological), C (Socio-economic) and D (Cultural) environments

removing bad odors and bird menace. Also, with the collection and sale of gas produced from the landfill as fuel, a part of the costs resulting from the implementation of this option will be compensated (Mondal and Dasgupta 2010).

The sanitary landfill due to the use of multilayer suitable coverage has the lowest contaminant emissions. So, it had the least negative score (RB: -A, RV = − 6) between other option for the PC1.

Public health is one of the most important biological–ecological (BE) components. Given the fact that proper sanitation is used in landfill, possible direct emissions of garbage, sodium and toxic gases to the surrounding environment are prevented. So using this option will cause the least negative impact on public health (RB: -A, RV = − 7). In contrast, the use of open dumping, as expected, has the most negative

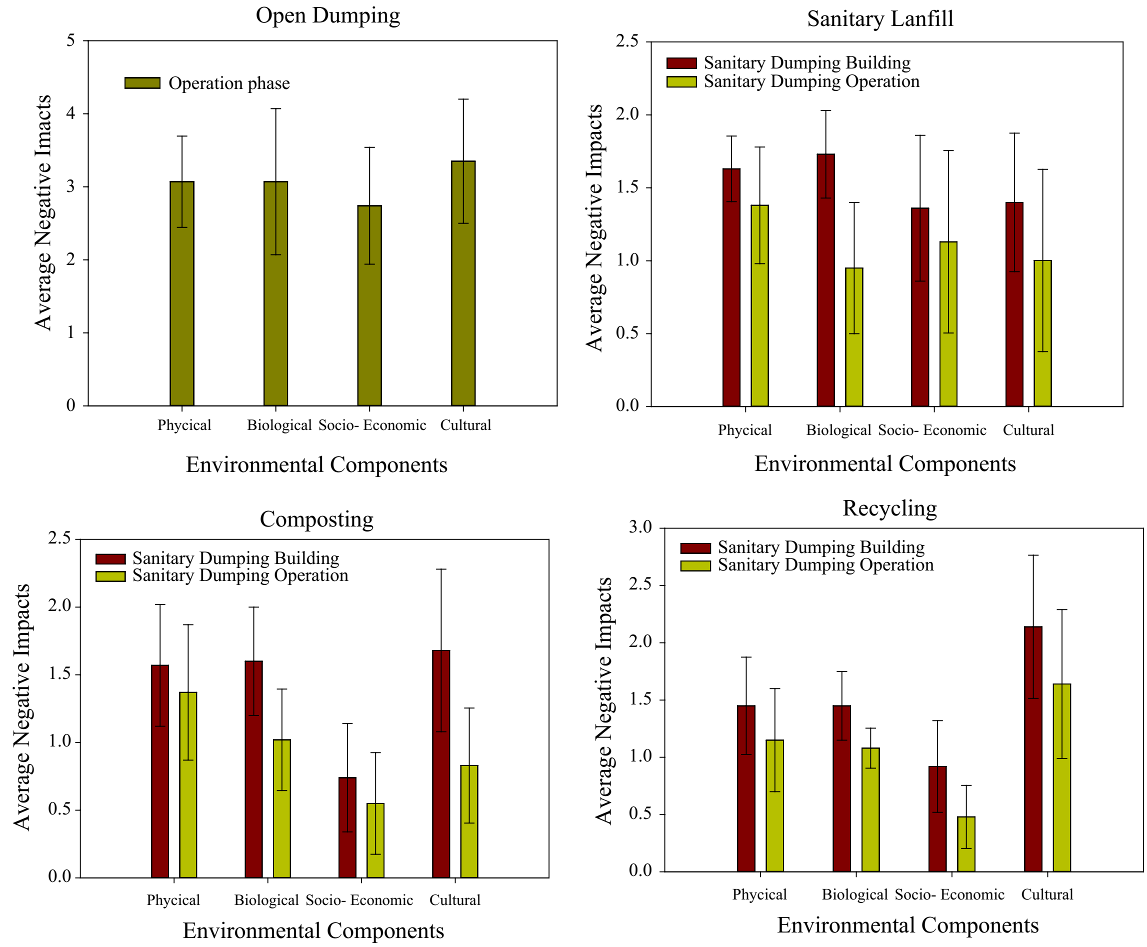

Fig. 4 EIA of MSW management on the environmental components

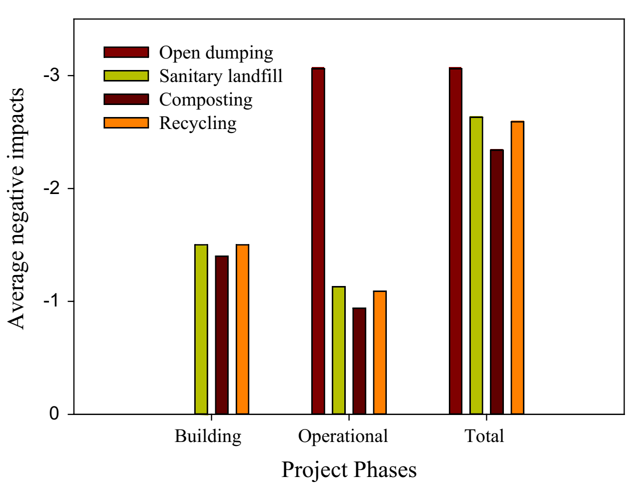

Fig. 5 Evaluate the effects of different options in the project phases

impact on public health compared to other options (RB: -E, RV = − 81).

Composting

Composting is a suitable method for management of the organic portion of MSW (Galgani et al. 2014). Also, composting is a possible MSW option, however, after elimination of plastic, metal and glass. The efficiency of composting will be affected by the stability and maturity of the product (Shen et al. 2015). The moisture content is the most important parameter in the composting process because water provides a possibility of dissolution and transport of nutrients that are required for microbial activity. Thus, the waste combination is important for implementation of the composting process. The composting option has several economic and environmental advantages including removing pathogens and weeds, decreasing the volume and mass of wastes, production of high-quality fertilizer, control and elimination of odors and consolidation of organic materials. (Petric et al. 2013). However, there are odor problems related to implementation of composting options that is mainly due to the plants that used from compost fertilizer (Zhang et al. 2013).

The suitable use of compost products will be improving quality of many biological–ecological (BE) components of the soil. Therefore, the components that are related to soil, such as plants and animals will be improved. That's why the compost has the highest positive impact on BE components compared with other MSW options. Also, the highest rates of negative effects on BE components belong to open dumping, because the waste and leachate deal directly with soil and related components.

According to area condition, benefits of composting products and also the MSW composition in Birjand, that mainly is corruptible, implementation of composting options was accepted by the residents. Therefore, composting has the most positive score in public acceptance (SC4) components with RB: C, and RV = 24. Regard to the effects of MSW management options on communities living near landfill (SC2), the result was obtained as follows: Range bonds equal (–D), (N), (–B) and (–D) for open dumping, sanitary landfill, composting and recycling, respectively. The negative impact of composting is mainly due to high odor emissions that are caused by decomposition of perishable material in the composting process. Therefore, it has negative effects on the communities that live near the landfill. The tourism (SC7) also is affected by odor emissions from landfill sites. So composting in addition to (SC2) has high negative impact on (SC7), with RB: C, and RV = − 24.

Assessing the effect of MSW options on the life quality of local people (SC10) has been considered the total resultant effects of each option. For example, despite the negative effects of composting option on odor emission, tourism and other components, many positive effects such as sales of composting products and increasing the population income level will be compensated the other negative effects. Therefore, the total effect of implementation of composting option with (RB: D, RV=54) is higher than other options. Then, the sanitary landfill (RB: C, RV = 32) and recycling (RB: B, RV=12) have the greatest positive impact, respectively. Open dumping (RB: -D, RV = − 63) has the most negative effects on SC10.

Recycling

Among important factors in the implementation of the recycling, the internal facilitators determined as strongest predictors of recycling. Consequently, it expressed that the consumer knowledge and education should be the best way to tackle internal barriers to recycling. Some external incentives, such as social influence and monetary rewards, also have a significant effect (Crociata et al. 2015).

The high negative impact of recycling about SC2 with RB: -D, and RV = − 54, that is why the recycling process requires many time, energy and costs for education and culture improvement of communities around the landfill, while other options are not mainly related to local communities. The recycling option also has a relatively high negative score in PC2 and PC3 with (RB: -C, RV = − 27) and (RB: -D, RV = − 36), respectively, because the leachate usually provided from separated wastes which are not managed.

The calculation of sustainability for the project options

According to Table 10, the amount of relative ES was calculated using the original ES in RIAM. Then, values of E, H_{NI} and *S*-level were calculated for each option. As appeared in Table 11, only the composting option with the *S*-level of "very weak" is sustainable. The sanitary landfill option comes next with the *S*-value of − 0.074.

Determining the sustainability in the Iranian Leopold matrix is different than RIAM method, because evaluation is performed in two phases of building and operation. In this method, the total scores of building and operation phases are used to determine the amounts of $\sum PC$, $\sum PC_{max}$, $\sum BE$, $\sum BE_{max}$, $\sum SC$, $\sum SC_{max}$, $\sum EO$ and $\sum EO_{max}$. The sustainability determination of the Iranian Leopold matrix suggested that the composting and open dumping options, with the *S*-value equal to − 0.162 and − 0.269, respectively, had the most and least sustainability. The determination of sustainability in the Iranian Leopold matrix is summarized in Table 12:

Choosing the best project alternative

In both methods, the PC environment received the highest negative score and also the lowest negative impact. Maximum positive impact was observed in the SC environment. The negative effects on the PC environment are mainly due to the construction procedure, which is the cause of natural imbalance and changes in the condition of soil, climate and region. Further, measures taken for maintenance of tools and machines, such as washing, moving and repairing machine parts, bring about several negative effects on chemical and physical components of environment. On the other hand, its positive effects on the SC are primarily to removing bad odors, eliminating gas emissions from the landfill and preventing the accumulation of harmful insects and animals and thereby preventing infections and promoting public health.

The results of RIAM revealed that sanitary landfill, as well as other options, exerted huge negative effects on the PC environment, which was due to change in topography and physical and chemical properties of soil and water caused by the construction of the landfill. Its positive effects were

Table 10 The total relative es for the project options, based on total original ES used in Mondal and Dasgupta (2010)

Component	Option 1: open dumping		Option 2: sanitary dumping		Option 3: composting		Option 4: recycling	
	Original ES	Relative ES	Original ES	Relative ES	Original ES	Relative ES	Original ES	Relative ES
PC1	−24	84	−6	102	−18	90	−12	96
PC2	−36	72	−14	94	−14	94	−27	81
PC3	−81	27	−14	94	−7	101	−36	72
PC4	−3	105	−8	100	−6	102	−6	102
PC5	−24	84	−24	84	−10	98	−24	84
PC6	−12	96	−28	80	−24	84	−48	60
PC7	−108	0	−54	54	−18	90	−54	54
PC8	−36	72	−18	90	−3	105	−9	99
PC9	−16	92	−81	27	12	96	0	108
PC10	−32	76	−8	100	0	108	0	108
	∑PC	708	∑PC	825	∑PC	968	∑PC	864
	∑PCmax	2160	∑PCmax	2160	∑PCmax	2160	∑PCmax	2160
BE1	0	108	9	117	48	156	−9	99
BE2	−4	104	8	116	54	162	0	108
BE3	−42	66	−9	99	−18	90	−36	72
BE4	−54	54	18	126	54	162	−9	117
BE5	−54	54	−18	90	−9	99	−9	99
BE6	−81	27	27	135	18	126	−9	117
BE7	−28	80	0	108	−5	103	−12	96
	∑BE	493	∑BE	791	∑BE	898	∑BE	708
	∑BEmax	1512	∑BEmax	1512	∑BEmax	1512	∑BEmax	1512
SC1	−18	90	−10	98	−10	98	−30	78
SC2	−36	72	0	108	−10	98	−54	54
SC3	−81	27	−7	101	−18	90	−36	72
SC4	−12	96	20	128	24	132	−18	90
SC5	−32	76	−20	88	−24	84	−9	99
SC6	−6	102	0	108	−8	100	0	108
SC7	−48	60	−10	98	−24	84	−20	88
SC8	−28	80	−12	96	−3	105	−3	105
SC9	20	128	48	156	63	171	27	135
SC10	−63	45	32	140	54	162	12	120
	∑SC	776	∑SC	1121	∑SC	1124	∑SC	949
	∑SCmax	2160	∑SCmax	2160	∑SCmax	2160	∑SCmax	2160
EO1	6	114	36	144	45	153	12	120
EO2	−36	72	−18	90	0	108	0	108
EO3	−8	100	−18	90	−20	88	−27	81
EO4	0	108	−24	84	−18	90	−18	90
EO5	−8	100	−36	72	−36	72	−27	81
EO6	8	116	24	132	−21	87	18	126
EO7	0	108	−12	96	0	108	−27	81
EO8	0	108	0	108	0	108	72	180
EO9	−12	96	−24	84	−36	72	−18	90
EO10	0	108	0	108	−15	93	0	108
EO11	0	108	0	108	63	171	0	108
	∑EO	1138	∑EO	1116	∑EO	1150	∑EO	1173
	∑EOmax	2376	∑EOmax	2376	∑EOmax	2376	∑EOmax	2376

Table 11 Calculated values of E, HNI and S−level in RIAM methods for MSW options in the Birjand

Project options	E	H_{NI}	S-value	S-level
Option 1–Open dumping	0.327	0.578	−0.251	N/A (Unsustainable)
Option 2−sanitary landfill	0.433	0.507	−0.074	N/A (Unsustainable)
Option 3–composting	0.508	0.499	0.01	Very weak (Sustainable)
Option 4–recycling	0.428	0.532	−0.104	N/A (Unsustainable)

Table 12 Summarize determination of E, H_{NI} and S (if appropriate) in the modified Leopold matrix for the MSW options of disposal site in Birjand

	Option 1	Option 2	Option 3	Option 4
$\sum$PC	2598	5510	5712	5973
$\sum PC_{max}$	7040	14,080	14,080	14,080
$\sum$BE	1709	4030	4092	4118
$\sum BE_{max}$	5120	10,240	10,240	10,240
$\sum$SC	2569	5504	5960	5942
$\sum SC_{max}$	6720	13,440	13,440	13,440
$\sum$EO	1654	3819	3790	3459
$\sum EO_{max}$	4480	8960	8960	8960
$\sum E$	0.354	0.392	0.403	0.415
$\sum H_{NI}$	0.623	0.584	0.565	0.580
S-value	−0.269	−0.192	−0.162	−0.165
S-level	N/A (UnSustainalbe)	N/A(Unsustainable)	N/A(Unsustainable)	N/A(Unsustainable)

mainly observed in the SC, which was related to preventing gas emissions and avoiding the huge impacts of open dumping.

The results of the Iranian Leopold matrix showed that the construction of the landfill and extensive excavations endangered the biological environment at the building phase. Yet, the benefits of the building phase outweigh the drawbacks. The building phase could, for example, minimize the direct contact of animals with buried waste. The results indicate that the negative effects of the recycling, composting and sanitary landfill options, at the construction phase, are far greater than the operation phase. Sociological economically speaking, there will be huge costs involved in the building phase, but the costs will be compensated at the exploitation stage by sale of recycled materials.

The results showed that the open dumping, with the final scores of − 1078 and − 3.21 in RIAM matrix and Iranian Leopold matrix, respectively, had the most negative impact, compared to other options. Open dumping, despite offering insignificant positive effects in the EO environment, has countless negative effects in other parts. However, it is still the most common option in waste management of Birjand. Open dumping, irrespective of its environmental impacts, is preferred over other options mainly because of the costs of other options, especially in the building phase, and the lack of funding in solid waste management projects.

In the Leopold matrix, the difference between sanitary landfill and recycling, with a final score of −2.63 and −2.59, respectively, was negligible. Yet, in the RIAM method, a significant difference was observed between the two options, with final scores of − 0.763 and − 1.184, respectively. Also, due to the vast lands allocated for the construction of a large landfill and considering the benefits of sanitary landfill in preventing the spread of contamination, the sanitary landfill seems to be the second reasonable option. According to the composition of the solid waste produced in Birjand which currently is recyclable about 24%, necessity of advanced equipment and high costs involve to establish a recycling plant, and sanitary landfill option appears to be more appropriate than recycling, particularly in the building phase. Finally, the results showed that composting with a final score of − 238 and − 2.34 in the RIAM matrix method and Iranian Leopold matrix, respectively, obtained the lowest negative scores between examined options. The moisture in waste combination increases microbial activity and rate of the composting process with the regulation of aeration and temperature. Thus, the presence of compounds with high moisture content increases the utility of the composting implementation. A low moisture content limited a biodegradation of organic matters and thus composting product to be unstable and immature (Shen et al. 2015). Due to the composition of waste disposed in Birjand, the greatest amount of residual organic household waste is perishable components such as meat, poultry and vegetables, representing about 76.95% of the total waste generated. On the other hand, composting process is based on the rapid degradation of waste collected. However, the amount of household waste is an important consideration in composting. Therefore, composting is the best and most logical option available for MSW management in Birjand.

Mondal and Dasgupta (2010) performed EIA of MSW disposal site in Varanasi using the RIAM method. Results show that the sanitary landfill is more suitable than other proposed options in current situation. El-Naqa (2005) used the RIAM method to examine three MSW management options in the city of Jordan, including improving the existing landfill, biogas production factory and the construction of sanitary landfill. Finally, the construction of a new sanitary landfill introduced as first priority. Also, Aliakbari Beidakhti et al. (2014) used RIAM method to evaluate the EIA of MSW options in the City of Mashhad. The results showed that the sanitary landfill was selected as the best MSW management option according to minimal environmental impact compared to other alternatives. As well as RIAM method has been widely used for assessing the environmental impact of the different projects worldwide. Li et al. (2014), for instance, remote sensing of environment applied an improved RIAM method for EIA of urban development in China. Gilbuena et al. (2013) used the RIAM technique for EIA of measures to reduce the harmful effects of flooding in Metro Manila, Philippines. Also, Taheri et al. (2014) used the RIAM for EIA of different MSW management in Tabriz city.

Aghnoum et al. (2014) evaluated forest management activities using Iranian Leopold Matrix. The results showed the predominance of the negative effects of management activities on the positive effects. Gholamalifard et al. (2014) applied the RIAM and Leopold matrix to assess the waste management options in Shahrekord. Based on results, the integration option of composting–recycling has the least negative environmental impacts and so was the first priority over the other options.

The difference between recent studies and the present study is due to the type of waste compound produced in Birjand that consist mainly from household waste which have putrescible organic materials. Due to the Birjand's climate which is warm and dry, the soil used in agricultural land is poor and has no nutrition for plants. Therefore, there is an urgent need to extensively apply the compost containing a lot of nutrients in these areas.

Conclusion

Fundamental issues in waste management in urban regions include collecting, separating, transporting, recycling and disposing of waste. With the development of urbanization worldwide, as well as diversity of consumption styles, the traditional methods of waste disposal are no longer useful. Due to expansion over recent years, Birjand, a density-populated urban region, has faced a huge waste disposal problem. Despite the measures taken to overcome the problem, the city is still seeking a proper method for disposal of urban waste. This study reviewed and evaluated the environmental impacts of different waste management options in the city of Birjand, including open dumping, sanitary landfill, composting and recycling. This study attempted to consider all of the aspects which influence solid waste management to offer the most appropriate option for waste management.

According to our surveys, there are important opportunities associated with waste management in the city, such as vast areas for disposal of waste, citizen awareness about waste, the provision of incentives for private sector participation and low levels of rainfall and humidity. The threats in this area include excessive heat, shortage of experts on the issue and lack of facilities and equipments.

Birjand has a hot and dry climate and its soil is devoid of nutrients, and also given the dire need for fertile soil in the region and the presence of perishable products in waste composition of the city, there is a considerable potential for converting these products into compost. Finally, due to the high amount of organic and perishable material in the urban solid waste, the composting option seems to be the best and most logical option for waste management in the city. Implementation of composting option has many benefits, such as the use of compost as fertilizer which provides nutrients for the soil organisms, improvement of soil structure, reduce soil erosion and increasing soil moisture. It also reduces the weight and volume of wastes and thus declines greenhouse and toxic gas emissions, leachate and as well as decrease the cost of its disposal. In addition, sales of compost compensated the cost of the project.

RIAM and Iranian Leopold matrix consider the impact of project activities on the all environment components and also have a high accuracy assessment. Thus, these methods are effective and have high performance for feasibility and environmental impact assessment.

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