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CASE STUDY

Industrial waste management using the rapid impact assessment matrix method for an industrial park

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ABSTRACT

Due to the growth of population and industrialization, a great number of problems associated with producing industrial wastes have been created for both the environment and human beings. The industrial waste management in Brujen industrial park, located in the western part of Iran, has been investigated in this study using the environmental rapid impact assessment matrix technique. For this purpose, the effective activities and components were classified. The determination of the best scenarios with the least impact on the environment was performed by developing the scenarios for possible industrial waste disposal and making calculations by the rapid impact assessment matrix method. The components of the environment were first classified into physical/chemical, economic/operational, biological/ecological, and social/cultural items. Afterward, with respect to the criteria of the rapid impact assessment matrix method, the importance of environmental impacts was determined by standard scoring of the developed scenarios. Ultimately, the environmental score of each component for the scenarios was calculated using the rapid impact assessment matrix method, and the best scenario with the least environmental impacts was selected through a quantitative comparison. According to the results, scenario 3 (pyrolysis) and scenario 1 (recycling) were found to have the most negative impact and the most positive impact on the environment. Scenario 4 (incineration), with its severe air pollution, obtained a high negative score and was excluded from the options. As a result, two systems of recycling (scenario 1) and the sanitary landfill (scenario 2) were identified as complementary to each other and were selected as a solid waste management method.

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INTRODUCTION

Various industries in industrial and semi-industrial countries are expanding with a great speed. One of the accepted ideas about boosting the efficiency is juxtaposing different industries in a restricted area known as industrial park. Collecting the industries in one location has some advantages such as facilitating better management, creating the necessary infrastructure, reducing the costs, controlling the pollution and creating more competition. However, it has some drawbacks such as producing different types of industrial waste depending on the type of high-volume industries (Abdoli and Pazoki, 2014; Geng *et al.,* 2007; Tavakoli *et al.,* 2020; Pazoki and Hasanidarabadi, 2017). Industrial parks have always had numerous problems concerning solid waste management. They spend many resources and, on the contrary, produce a high amount of industrial solid waste which is responsible for many pollutants and irreparable damage to the environment (Zhang *et al.,* 2016). Most of the industrial parks in Asian countries, such as Iran, are facing the problems of waste management and choosing a proper method for their production wastes disposal (Azari *et al.,* 2019; Koolivand *et al.,* 2017). There are different methods for industrial waste management such as sanitary landfill, incineration, pyrolysis, recycling and so on, each of which has its own merits and demerits (Naveen *et al.,* 2017; Xin-gang *et al.,* 2016; Chen *et al.,* 2014; Andreola *et al.,* 2016). In this regard, integrated solid waste management should be followed aiming at sustainable development and simultaneously the topics of environmental impacts, economic conditions, social acceptance and aesthetic should be considered to ensure the selection of a proper method for industrial waste management (Mc Dougall *et al.,* 2008). Environmental Impact Assessment (EIA) method can be used to make a decision about a plan, a policy, a program or a project. EIA is, in fact, a systematic method to recognize and investigate the positive and negative environmental impacts physically, biologically, socially and economically. This method can be applied to a plan, a policy, a program or a project (Mondal and Dasgupta, 2010; Wang *et al.,* 2006). Nowadays, comprehensive environmental impact assessment is required for planning, designing or establishing any project (Karbassi and Pazoki, 2015; Shams Fallah *et al.,* 2013). Although EIA is known as a useful tool for improving planning decisions, it has always been blamed for subjective assessments which are difficult to quantify and present, leading to much criticism on EIA as a tool with lack of transparency. Acceptance of the 'domino effect' of actions has moved environmental assessments away from simple impact predictions on biota into a wider, holistic form that is common today. This move towards holistic EIA has, until now, increased the complexity and subjectivity of the final environmental impact assessment (Baba, 2007). Rapid Impact Assessment Matrix (RIAM) was developed to overcome these drawbacks in execution and reporting of EIA (Hoveidi *et al.,* 2013; Gilbuena *et al.,* 2013). RIAM is one of the EIA tools which is carried out based on analyzing the environmental activities and matrix of parameters (Phillips, 2012). This method was first established by Pastakia in 1998 (Pastakia and Jensen, 1998) who used specific standards for assessment of important criteria. In this method, after identifying the activities of the proposed plan, their impacts on each physical/chemical, biological/ecological, social/cultural and economic/operational parameter are specified. Moreover, a score is assigned to each environmental component using a defined criterion. After performing the assessment based on the mentioned criteria and mathematical calculations, the impacts are set in a range of highly positive to highly negative. Finally, the analysis is accomplished by applying the tables and related diagrams to the environmental components and predicted impacts. RIAM method has been used in many studies and projects and is an appropriate tool for recognizing the impacts on the environment. For example, Suthar and Sajwan (2014) assessed the environmental impacts of an urban waste landfill and selected a location for sanitary landfill in India using the RIAM method. They divided different physical, biological, social/cultural and economic criteria of the project into some sub-criteria and used them to choose the best available scenario (Suthar and Sajwan, 2014; Li et al., 2014). In another similar study, EIA was performed by the RIAM method in order to choose a scenario from the different scenarios related to disposing of urban wastes. The different scenarios used in the mentioned study were accumulation of waste, sanitary landfill, gasification, incineration, and biomethanisation. Sanitary landfill has been selected as the best option depending on the conditions of study (Mondal and Dasgupta, 2010; El-Naqa, 2005). In another study, the RIAM technique was used for three options of promoting landfill, constructing a biogas digester at the landfill and replacement of the landfill, and finally replacement of the landfill was identified as an appropriate option (El-Naga, 2005). Using the EIA method with the RIAM technique has been followed in many plans, studies, and projects such as water resource management or water system restoration (Shakib-manesh *et al.,* 2014; Araujo *et al.,* 2005), construction (Pazoki *et al.,* 2014), synthesis of biofuels (Upham and Smith, 2014), municipal solid waste disposal site (Aliakbari-Beidokhti *et al.,* 2017), petrochemical industries (Hoveidi *et al.,* 2013) and so on. RIAM has been widely employed by many researchers to solve the multi-criteria decision problems (Hoveidi et al., 2013; Li *et al.,* 2014; Shakib-manesh *et al.,* 2014). This method is one of the multi-criteria decision techniques with many capabilities used in different scientific disciplines. It is suitable for solving complicated issues such as management, resource allocation, urban development planning and project design. This approach has been developed, tried and tested to select the best option to meet a set of goals and criteria. Considering the problems caused by industrial wastes of Brujen industrial park, its waste management has been assessed through environmental impacts assessment of different methods for the disposal of industrial wastes including sanitary landfill, recycling, incineration and pyrolysis using the RIAM technique. It is the first time that RIAM is applied to 4 scenarios including recycling, sanitary landfill, pyrolysis and incineration in an industrial park. This study has been carried out in Brujen city, Iran in 2019. The data used in this study belong to the industrial waste management master plan of Brujen industrial park in 2016, because the number of industrial units and their production have not been changed significantly since 2016.

MATERIALS AND METHODS

Case study

Brujen city, with an area of 2064 km^2, is located in the east of Chaharmahal Province (Fig. 1). The city with an altitude of about 2200 m above sea level lies between longitude of 51° 17′ E and latitude of 32° 11′ N. Brujen industrial park, located in Brujen city, has an area of 524.77 ha, in which the total area intended for the existing industries is 144 ha and the area allocated to streets, green and empty spaces of industries is 380.7 ha.

According to zoning, Brujen industrial park has

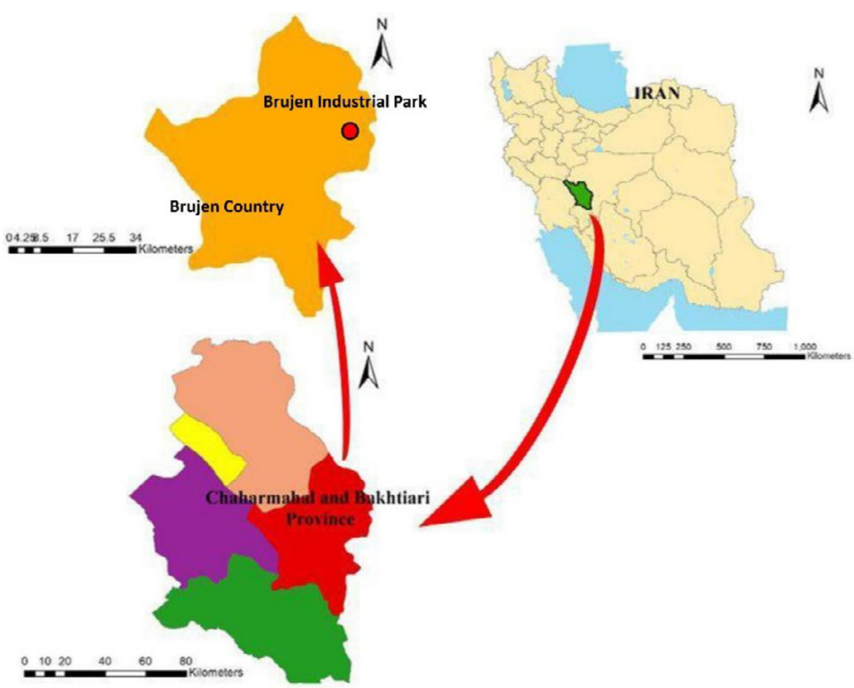

Fig. 1: Geographical location of the study area in Brujen, Iran

been divided into 7 industrial sections including chemical, metal, non-metallic mineral, food, textile, electricity, electronic and service zones. The number of different types of industries, their area and the population of each unit in Brujen industrial park has been shown in Table 1.

Various wastes were classified by their types. In fact, this classification is a type of physical analysis and included 7 groups. The share of each unit in producing metal, plastic, chemical, food, textiles, and non-metallic minerals has been presented in Table 2. The total waste produced in Brujen industrial park is 757,225 kg/mo.

Based on the industrial waste management master plan study, the population of Brujen industrial park was 2,616 people and per capita of food waste generation was 0.84 kg/day per person. Generally, 2200 kg/day food waste is produced in Brujen industrial park. The majority of this waste is mainly collected from several dining rooms for staff distributed in the park. Table 3 presents some of the methods currently used in Brujen industrial park for collecting, maintaining and transporting the waste to the disposal site. It should be noted that in this industrial park, non-recyclable industrial waste is collected, maintained and transported along with sanitary wastes simultaneously. Generally, the main methods currently used for waste disposal can be summarized as 1) Transferring to the pile on a weekly basis, 2) burning in the workplace, 3) transferring to municipal sites, and 4) unsanitary disposal around the industrial park. This waste can lead to severe environmental pollution over time. Depending on the method used for waste disposal, air, soil and water pollution can negatively affect the residents' health both directly or indirectly.

Table 4 presents the types of industries and the number of them that use temporary storage,

Table 1: Specifications of each industrial unit in Brujen industrial park

Industries	Number of units	Area (m^2)	The total population of active units (person)
Chemical	38	210,000	551
Metal	42	157,000	564
Non-metallic Mineral	11	96,000	185
Food	24	150,000	481
Cellulose	8	32,000	50
Textiles	26	510,000	785
Electricity and electronics	4	10,000	-
Services	24	10,000	-
Total	177	1,175,000	2616

Table 2: The share of each industry in producing various waste types

No	Industries	Waste type						
		Metal (%)	Plastic (%)	Cellulose (%)	Chemical (%)	Food (%)	Textiles (%)	Non-metallic mineral (%)
1	Chemical	0	40	5	70	0	0	0
2	Metal	80	5	0	10	0	0	0
3	Non-metallic mineral	0	5	0	0	0	0	0
4	Food	0	20	5	0	100	0	0
5	Cellulose	0	5	80	5	0	0	0
6	Textiles	5	5	5	10	0	95	0
7	Electricity and electronics	15	10	0	5	0	0	0
8	Services	0	10	5	0	0	5	0
	Total	100	100	100	100	100	100	0

Table 3: The methods of collecting, temporary storage and waste transport in Brujen industrial park

Method		Number of industries
Collection and temporary storage	Piling up	52
	Metal containers	2
	Special containers	-
	Keeping in sack	4
	Other items	7
Status of temporary storage	Indoor	24
	Outdoor	41
	Available to insects	54
	Capable of contaminating soil	21
	Available to vermin	29
	Only a fence alongside	13
	Capable of air polluting	25
	Capable of contaminating surface water	12
	Capable of contaminating groundwater	19
The vehicles used for transporting the waste to disposal sites	Pickups	40
	Truck	3
	Garbage wagon	-
	Other items	22
Status of transportation to disposal sites	Indoor	-
	Outdoor	31
The organization which transports waste to disposal sites	Industrial workshop	27
	Private organization	29
	Municipality	-
	Other items	9

Table 4: The number of industrial units with temporary storage, waste collection and transportation systems in Brujen industrial park

No.	Industries	Temporary storage	Waste collection	Waste transportation
1	Chemical	38	14	4
2	Metal	42	27	13
3	Non-metallic mineral	11	4	2
4	Food	24	4	3
5	Cellulose	8	3	2
6	Textiles	26	8	5
7	Electricity and electronics	4	4	1
8	Services	24	1	1
Total		177	65	31

collection and transport system for their wastes. All industrial units in Brujen industrial park have temporary storage but some of them have waste transportation and waste collection systems.

Applied methods

The RIAM method was used to assess the environmental impacts of Brujen industrial park, (Pastakia and Jensen, 1998). This assessment was performed in three steps of 1) holding discussions and exchanging views with experts to determine the impacts on different factors of the environment using initial checklists; 2) determining the rapid matrix components including the criteria of groups A and B; and 3) assessment by rapid matrix and determining the results. For this purpose, a matrix consisting of the assessment criteria of physical/chemical (PC), biological/ecological (BE), cultural/social (SC)

Table 5: The assessed indices and their subsections

Physical/chemical components	Economic/operational components
The existing waste	
Leachate produced in the current landfill	The cost of building a new landfill
Leachate collection using the drainage system	The cost of expanding the current landfill
Reuse and discharge of leachate	Leachate collection costs
Recycled leachate discharge to the urban wastewater	The cost of leachate treatment
Current status of utilities for recycling and purification	The cost of monitoring and sampling analysis of the waste
Leakage of leachate into groundwater	The cost of occupying a new land for utilities
Odor control	The cost of establishing waste incinerator and its operation
Greenhouse and non-greenhouse gas emissions	The cost of recycling
Recycling and controlling methods of greenhouse and non-greenhouse gases	The cost of waste collection
Processing and purification of ash produced by burning the industrial waste from the park	Revenue of production and energy generated from recycling or incineration
Biological/ecological components	**Social/cultural components**
Effects on groundwater by the release of leachate	Residential areas at the vicinity of the landfill
Effects on soil	People's problems caused by dust
Effects on ecosystems	People's problems caused by noise
Effects on corrosion and decomposition of waste	Public opinion regarding the use of recycled materials and entrepreneurship in the region
Soil erosion and runoff of excess	Problems caused by the smell of industrial waste of the park
Risks of outdoor landfill	Employment in the region

and economic/operational (EO) parameters was provided. The most important details of the related activities have been explained in Table 5. In the next stage, the impacts of project activities on the environmental factors were scored using the defined criteria. The assessment criteria were divided into two groups according to the RIAM method as 1) the most important criteria which could noticeably influence the obtained score (the criteria of group A, including A1 and A2); and 2) the relatively important criteria which could not significantly influence the obtained score (the criteria of group B, including B1, B2, and B3). In this scoring system, the scores related to criteria of group A were multiplied (Eq. 1). Therefore, these criteria have a higher weight in scoring. The scores related to group B were added to each other (Eq. 2). Therefore, the criteria of group B have a lower weight but their final value is considered in scoring. The results of Eqs. 1 and 2 were multiplied to determine the final value of environmental assessment or Environmental Score (ES) using Eq. 3. All the equations were presented according to Pastakia and Jensen (1998).

$$(A_1) \times (A_2) = A_T \tag{1}$$

$$(B_1) + (B_2) + (B_3) = B_T \tag{2}$$

$$(A_T) \times (B_T) = ES \tag{3}$$

Where, (A_1) and (A_2) is the effective criteria related to group A; (B_1) and (B_2) is the effective criteria related to group B; (A) is the result of multiplying all criteria of A; (B) is sum of all criteria of B, and ES is the environmental score for conditions.

In group A, criterion A_1 represents the importance of impact and criterion A_2 shows the size, and in group B, criteria B_1, B_2 and B_3 show the impact of stability, reversibility and cumulative respectively (Table 6). The scores for each individual aspect were calculated by evaluation criterion described by Pastakia and Jensen (1998). It is obvious that the nature of impact was first specified in terms of being positive or negative and then scoring was done.

To analyze the scoring results obtained by the intended method, the results of ES operations (calculated by Eq. 3) were compared in the ranges given in Table 7. The needed categories were formed to be compared with other categories in Table 7 and to classifying the scores. For this purpose, first, the ranges of positive and negative impacts for each section of the environment were determined. The score related to each range has been shown in Table 7. Finally, the option with the minimum negative impact on the environment was chosen.

Table 6: Criteria and their scoring in the RIAM method

Criterion	Score	Description
Importance of condition: A_1	4	Important to national/international interests
	3	Important to regional/national interests
	2	Important to areas immediately outside the local condition
	1	Important only to the local condition
	0	No importance
The magnitude of change/effect: A2	3	Major positive benefit
	2	Significant improvement in the status quo
	1	Improvement in the status quo
	0	No change to the status quo
	-1	Negative change to the status quo
	-2	Significant negative change
	-3	Major dis-benefit or change
Stability: B_1	1	No change
	2	Temporary
	3	Permanent
Reversibility: B_2	1	No change
	2	Reversible
	3	Irreversible
Cumulative: B_3	1	No change
	2	non-cumulative/single
	3	cumulative/synergistic

Table 7: Converting given scores to the range of categories

Environmental score (ES)	Range value	Description of range band (change/impact)
+72 to +108	+E	Major positive
+36 to +71	+D	Significant positive
+19 to +35	+C	Moderate positive
+10 to +18	+B	Positive
+1 to +9	+A	Slight positive
0	N	No change/status quo/not applicable
-1 to -9	-A	Slight negative
-10 to -18	-B	Negative
-19 to -35	-C	Moderate negative
-36 to -71	-D	Significant negative
-72 to -108	-E	Major negative

Table 8: Waste management scenarios in Brujen industrial park

Scenario	
1	Recycling
2	Sanitary landfill
3	Pyrolysis
4	Incineration

Generally, 4 scenarios were proposed to investigate the methods for waste management and disposal by RIAM in Brujen industrial park (Table 8).

Considering the scenarios presented in Table 8 and all mentioned effective criteria, a questionnaire was prepared and distributed among the staff of Brujen industrial park, residents in the vicinity of the industrial park and a group of environmental experts.

RESULTS AND DISCUSSION

The results of each scenario were investigated and as an instance, the table related to the assessment of scenario 1 through the RIAM method has been shown in Table 9.

Scenario 1 (recycling)

As can be seen in Table 9, the components related to physical/chemical criterion are 11 cases, the components of biological/ecological criterion are 6

Table 9: Assessing scenario 1 through RIAM method

Scenario 1									
Components	A_1	A_2	B_1	B_2	B_3	A_T	B_T	ES	RV
Physical/chemical components									
The existing waste	2	3	3	2	3	6	8	48	D+
Leachate produced in the current landfill	2	-2	2	2	3	-4	7	-28	C-
Leachate collection using the drainage system	2	1	2	1	1	2	4	8	A+
Reuse and discharge of leachate	2	2	3	3	3	4	9	36	D+
Recycled leachate discharge to the urban wastewater	3	1	1	1	1	3	3	9	A+
Current status of utilities for the recycling and purification	3	-2	3	1	1	6	5	-30	C-
Leakage of leachate into groundwater	2	-1	3	3	3	-2	9	-18	B-
Odor control	2	1	1	1	1	2	3	6	A+
Greenhouse and non-greenhouse gas emissions	2	-1	3	3	3	-2	9	-18	B-
Recycling and controlling methods of greenhouse and non-greenhouse gases	2	-1	3	3	3	-2	9	-18	B-
Processing and purification of ash produced by burning the industrial waste from the park	2	1	1	1	1	2	3	6	A+
Biological/ecological components									
Effects on groundwater by leachate release	2	-1	3	3	3		9	-18	B-
Effects on soil	2	-1	3	3	3	-2	9	-18	B-
Effects on ecosystems	2	-1	3	3	3	-2	9	-18	B-
Effects on corrosion and decomposition of waste	1	-2	3	3	3	-2	9	-18	B-
Soil erosion and runoff of excess	1	-1	2	2	3	-1	7	-7	A-
Risks of outdoor landfill	1	-2	3	3	3	-2	9	-18	B-
Social/cultural components									
Residential areas at the vicinity of the landfill	2	2	2	2	3	4	7	28	C+
People's problems caused by dust	2	2	2	2	2	4	6	24	C+
People's problems caused by noise	2	-2	2	3	2	-4	7	-28	C-
Public opinion regarding the use of recycled materials and entrepreneurship in the region	2	3	3	3	3	6	9	54	D+
Employment in the region	3	2	2	3	2	6	7	42	D+
Problems caused by smell of industrial waste of the estate	2	-2	2	3	3	-4	8	-32	C+
Economic/operational components									
The cost of building a new landfill	1	2	2	2	2	2	6	12	B+
The cost of expanding the current landfill	2	2	2	2	2	4	6	24	C+
Leachate collection costs	2	2	3	3	3	4	9	36	D+
The cost of leachate treatment	1	2	1	1	2	2	4	8	A+
The cost of monitoring and sampling analysis of waste	2	1	2	2	2	2	6	12	B+
The cost of occupying a new land for utilities	2	-3	2	2	2	-6	6	-36	D-
The cost of establishing waste incinerator and its operation	2	1	3	3	2	2	8	16	B+
The cost of recycling	1	2	2	2	2	2	6	12	B+
The cost of waste collection	1	-1	2	2	2	-1	6	-6	A-
Revenue of production and energy generated from recycling or incineration	2	3	3	3	3	6	9	54	D+

*In all Tables and diagrams, EO represents the economic/operational components, SC represents the social/cultural component, BE represents the biological/ecological components and PC represents the physical/chemical components.

cases, the components of social/cultural criterion are 6 cases and the components of economic/operational criterion are 10 cases. The ES is used to classify the impact in terms of the degree of change, which is indicated by a range band (RB).

In this step, 4 scenarios were compared to evaluate the impacts of scenarios in terms of the related impacts on the environmental factors. A summary of the positive and negative impacts of the ranges in each scenario has been displayed in Figs. 2 to 5.

Considering the physical/chemical section of the first scenario (recycling) presented by Fig. 2, the sub-criteria of leachate produced, leakage of leachate into groundwater, greenhouse and non-greenhouse gas emissions and current status of the utilities have negative impacts on the environment of the industrial park. Obviously, positive scores are more than

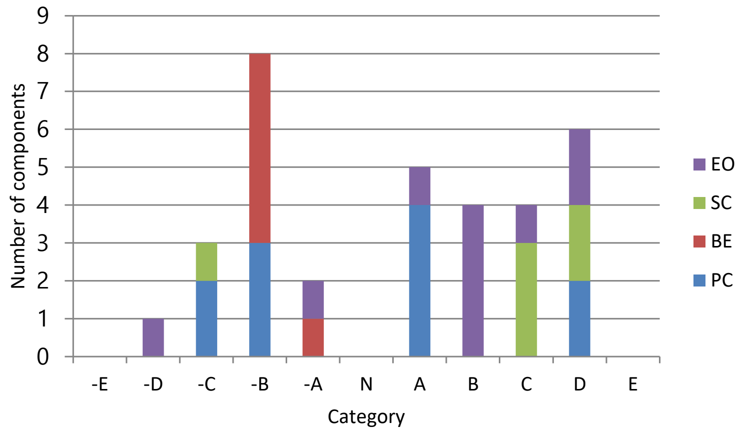

Fig. 2: Assessment of scenario 1 (recycling) by the RIAM method

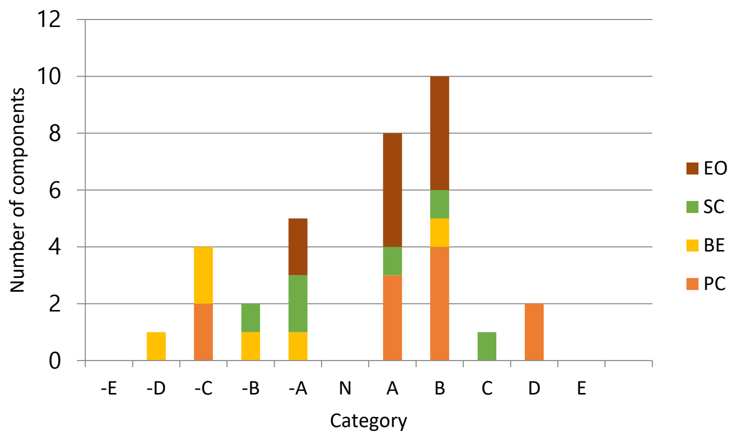

Fig. 3: Assessment of scenario 2 (sanitary landfill) by the RIAM method

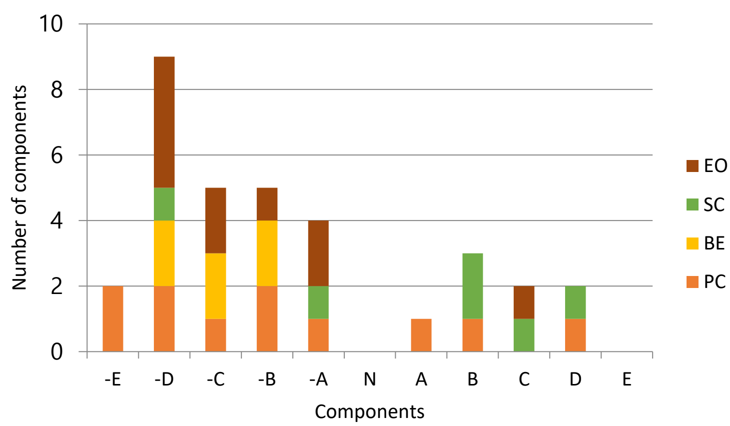

Fig. 4: Assessment of scenario 3 (pyrolysis) by the RIAM method

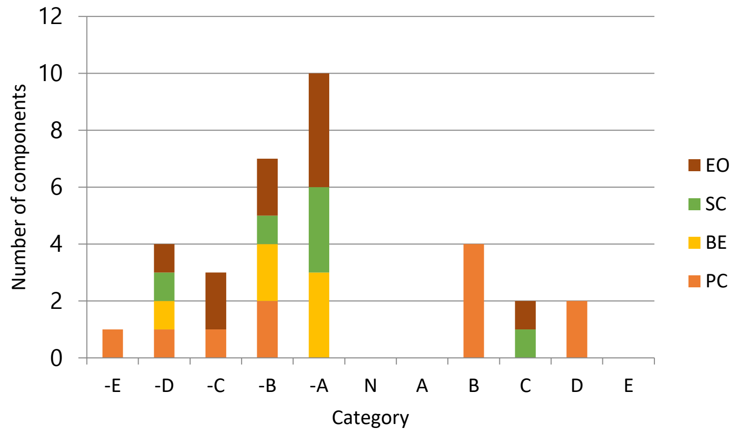

Fig. 5: Assessment of scenario 4 (incineration) by the RIAM method

negative ones. In the biological/ecological section, all the sub-criteria have negative impacts. This result was predictable since all types of waste materials cannot be recycled. Considering the negative impacts, their influence is not considerable and they are unlikely to pose a serious threat to the environment. In the social/cultural section, only the problems associated with noise and smell of waste in depot sites have a negative impact. Producing a new product and effective advertisements to improve the culture of the society received a positive score due to the reduction of waste volume. Employment is another parameter that has a high positive score. In terms of economic/operational parameters, the recycling method can be deemed as one of the most economic methods with high positive scores. Despite requiring special equipment, the recycling method can provide a huge economic resource and capital return. It should be noted that capital return can compensate for a large part of the costs associated with the land and equipment required in this method. Hence, D+ was assigned to the highest positive impact on the revenue of production.

Scenario 2 (sanitary landfill)

Environmental impacts related to scenario 2 (sanitary landfill) for each component have been shown in Fig. 3. In the physical/chemical section of scenario 2 (sanitary landfill), the negative impacts are assigned to leachate produced in disposal sites, leakage of leachate into groundwater and greenhouse gas emissions. The impact of leachate and greenhouse gases could be greater but their impact reached the minimum amount as a result of the sanitary landfill and providing the utilities including collecting and purification of leachate and emitted gases (pazoki *et al.,* 2015). If the produced leachate enters the urban wastewater system and it can be purified in that system, there will be no negative impact on the environment (Ghasemzade and Pazoki, 2017; Pazoki *et al.,* 2017).

In terms of biological/ecological components, an environmental disaster will occur if leachate is released into the groundwater because the geomorphology of the area will let the pollution of groundwater to be rapidly spread throughout the area. This is probably why the impact on groundwater is the most destructive factor for the environment if leachate is released. The environmental score of biological/ecological components falls within range D-. The only positive impact on the environment in the biological/ecological section is related to the impact of sanitary landfill on corrosion and decomposition of wastes. Sanitary landfill increases the speed of materials decomposition and reduces the volume of materials. In the social/cultural section, some issues such as dust and noise cause some problems in the adjacent areas. Moreover, daily discharge of waste into the landfill causes some problems such bad smell of organic wastes. If the sanitary landfill is conducted profoundly, it will provide many job opportunities and the majority of people can work in it as it does not require a specific skill. Over recent years, this method has also been accepted by the public because of its advantages. The only high price to be spent in this method is the cost of the land which is required for landfilling.

Scenario 3 (pyrolysis)

Considering Fig. 4, scenario 3 (pyrolysis) has numerous negative points in terms of physical/chemical components. Pyrolysis method cannot be applied to all the existing wastes as it only supports some specific cases including organic materials. As a result, it has a negative score for the type of waste. The gas emitted from the pyrolysis system is less than the gas emission from the incinerator but it causes more contamination. In addition, controlling the odor and gas emitted from this system is difficult and the concentration of dioxins is high in it. Scenario 3 (pyrolysis) has a negative score in all cases in terms of biological/ecological components and is not environmentally suitable.

Scenario 3 (pyrolysis), in terms of social/cultural components, only makes problems in the sub-criterion because of odor and therefore receives a negative score. Knowing that it is a new method in urban waste management, it may gain a positive score in other cases. Moreover, it does not have noise pollution and helps in job creation in the area. It should be noted that the third scenario (pyrolysis), in which new technology is used and drying of the material is required at the beginning of establishment, requires a high cost in terms of economic/operational section. Therefore, the costs of constructing a new landfill, expanding a disposal site, and collecting and purifying leachate are extremely increased, leading to a high negative score in this section.

Scenario 4 (incineration)

Fig. 5 illustrates that scenario 4 (incineration) has a negative impact on the environment in the physical/chemical section; sub-criteria of waste volume in the park and produced leachate; current status of utilities for recycling, purifying and collecting leachate; leachate leakage into the groundwater; and greenhouse gas emissions; processing and purifying the ash from incinerating the industrial wastes; and current disposal site. All components in the biological/ecological section have negative impacts, showing that definitely, it is not suitable for the environment.

This scenario has undesired impacts on residential areas in the vicinity of the disposal site and also leads to many problems such as noise pollution, dust and smell of waste in the social/cultural section. Considering the result of questionnaires, incineration has undesired impacts in the economic/operational section probably due to requiring a lot of equipment and maintenance of incinerators. However, it has a positive score in the sub-criterion of revenue of production and generated energy and many negative scores in the economic/operational criteria. The largest impact of scenario 4 is on the weather. The produced pollution mainly stems from NO_2, SO_2 and NO_X particles which have negative impacts on human health (physically, chemically, biologically, ecologically and sociologically negative impacts). However, the most important positive impact of incineration is reducing the volume of waste, which leads to reducing the problem of waste accumulation. As can be seen in Table 9 and Fig. 6, scenario 1 (recycling) and 2 (sanitary landfill) have the minimum environmental impact on the waste management in Brujen industrial park. Scenarios 3 (pyrolysis) and 4 (incineration) have

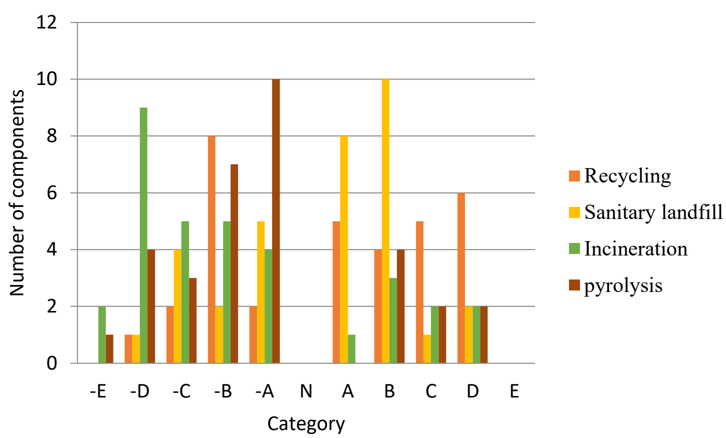

Fig. 6: Comparison of the scenarios assessed by the RIAM method

the maximum negative impact on the environment. Scenario 3 (pyrolysis) and 1 (recycling) have the most negative and the most positive impacts on the environment respectively. Scenario 4 (incineration) has the most negative impact on air pollution which has an adverse impact on human health. However, the most important positive impact of incineration is reducing the volume of waste, which leads to the reduction of waste accumulation.

The results obtained from the proposed scenarios imply that recycling and sanitary landfill are in the first priority to be used in a disposal site and to reduce the pollution. Considering the conditions of the study area, waste type and current knowledge, pyrolysis and incineration are not recommended because of their impact on physical/chemical, economic/operational, biological/ecological, and social/cultural items. This method (RIAM) can be used in any waste management scenario in any industrial park. For example, Hoveidi (2013) implemented RIAM method for waste management in Toos industrial state in Mashhad. He considered various disposal options such as open dumping, sanitary landfill, gasification and incineration from the viewpoints of physical, chemical, biological, ecological, cultural, social, economic and environmental aspects. The obtained results showed that sanitary landfill led to more beneficial effects than other four options. Therefore, the best method was selected for waste management in Toos industrial estate in Mashhad was selected.

CONCLUSION

RIAM is the most suitable method for solving complicated issues such as waste management. This approach was developed, implemented and tested to select the best option to satisfy a set of goals and criteria. It was found suitable for waste management as a complicated issue in developing countries, especially in industrial parks because they produce a wide range of hazardous wastes which can have direct adverse effect on health, environment, economy and society. Hence, RIAM was used as a multi-criteria decision technique for waste management in Brujen industrial park. Four scenarios considered in this study were sanitary landfill, incineration, pyrolysis and recycling. The results obtained from the proposed scenarios imply that recycling and sanitary landfill are in the first priority to be used in a disposal site and to reduce the pollution. Considering the conditions of the study area, waste type and current knowledge, pyrolysis and incineration are not recommended. Pyrolysis is in the second priority due to releasing hazardous pollutants, such as NO_2, SO_2 and NO_x, and bearing high costs. It was found that simultaneous application of the mentioned two methods for waste disposal in Brujen city could provide the advantage of reducing negative impact on the environment because some types of the existing waste could not be recycled and it was not economical to burry all the existing waste. As a result, the two methods could be recommended as complementary to each other for waste management in Brujen industrial park.

CONTRIBUTIONS AUTHOR

M. Kian A.A. Shayesteh and F. Khodiopour performed the study data. did the calculations in common with M. Pazoki. R. Ghasemzadeh and O. Koohshekan designed the model and the computational framework and analyzed the data. M. Pazoki was responsible for overall planning and directing. In addition, she has provided a comprehensive review and edited the manuscript.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

+A	Slight positive change/impact
+B	Positive change/impact
+C	Moderate positive change/impact
+D	Significant positive change/impact
+E	Major positive change/impact
-A	Slight negative change/impact
A1	Importance of condition
A2	The magnitude of change/effect

-B	Negative change/impact
B1	Permanence
B2	Reversibility
B3	Cumulative
BE	Biological/ecological components
-C	Moderate negative change/impact
-D	Significant negative change/impact
-E	Major negative change/impact
EIA	Environmental impacts assessment
EO	Economic/operational components
Eq	Equation
ES	Environmental score
ha	hectare
kg/mo	Kilogram/Month
km^2	Square kilometer
m^2	Square meter
min	Minute
N	No change/status quo/not applicable
NO_2	Nitrogen dioxide
NO_x	Nitrogen Oxides
PC	Physical/chemical components
RB	Range band
RIAM	Rapid impact assessment matrix
RV	Range value
SC	Social/cultural components
SO_2	Sulfur dioxide

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