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Assessment of Disposal Scenarios for Solid Waste Management Using Fuzzy Rapid Impact Assessment Matrix; a Case Study of Khorramabad Industrial Estate

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ABSTRACT: The present paper tries to assess different scenarios for solid waste management in Khorramabad industrial park. It uses a new hybrid method of fuzzy Rapid Impact Assessment Matrix, and proposes the Fuzzy theory, the ranking method of which is innovated so that the accuracy and flexibility of the RIAM method could be improved. Four scenarios are studied, namely open dumping, sanitary landfill, gasification, and incineration. They are then evaluated in terms of their physical/chemical, biological/ecological, social/cultural, and economic/operational effects. Afterwards, two scenarios have been selected with the aim of energy production. The evaluation of these aspects for each scenario is in accordance to the expert's judgments and field study, with the results showing that sanitary landfill has had the least undesirable effects. Hence, this approach is selected as the best scenario for waste management in the studied area. According to the obtained results, it is suggested to consider sanitary landfills as the main part of the waste management hierarchy program of the studied area. Also, it is highly recommended to use the Fuzzy RIAM technique in similar studies and to compare the results with the new ones in order to examine the accuracy of the new improved method.

Keywords: Solid waste, Fuzzy theory, disposal methods, environmental impact assessment.

INTRODUCTION

Solid waste management of the industrial estate is a very important issue in developing countries (Koolivand et al., 2018). Lack of proper planning for waste disposal results in extensive pollution of surface and groundwater resources, not to mention soil pollution (Bain et al., 2010). Solid waste management of an industrial estate is one of the main parts of comprehensive waste management that requires specific management systems (Heidrich et al., 2009). What is more, proper disposal of industrial waste has become an important global issue (Zvijáková et al., 2014). Increasing generation of wastes due to industrial development and population growth has also attracted increasing attention to proper management and disposal of industrial wastes (Nouri et al., 2018). One of the most essential problems that needs to get solved by industrial waste management is to determine the effective tools for assessment of different disposal methods (Nouri et al., 2012). The proper method of

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assessment is very important for industrial waste management (Costa et al., 2010). Proper assessment tools can enhance waste management efficiency and reduce environmental effects (Morgan, 2012). Therefore, industrial managers always try to find an effective tool to assess different disposal methods and select the best one. The Rapid Impact Assessment Matrix (RIAM) is one of the best tools for assessment of disposal methods, thanks to its analysis structure and process (Mondal & Dasgupta, 2010). Recently, it has been applied to assess solid waste management. The use of the RIAM method helps enhancing the efficiency of the solid waste management process (Hoveidi et al., 2013). Many types of research in the field of waste management demonstrate the advantages of these methods (Mondal & Dasgupta, 2010; Daryabeigi Zand & Vaezi Hier, 2019; Hoveidi et al., 2013; Taheri et al., 2014; Aliakbari-Beidokhti et al., 2017; Padash, 2017; Valizadeh & Hakimian, 2019). Despite all of its benefits in waste management, there has been fewer studies that focus on the use RIAM with Fuzzy theory. As a result, the current paper proposes a new hybrid method of FRIAM, which is based on Fuzzy theory and could be used to assess different disposal scenarios. The study employs RIAM method in combination with Fuzzy theory to assess disposal scenarios for solid waste management of the Khorramabad industrial park. The proposed FRIAM model can be applied not only to assess disposal scenarios but also to improve the solid waste management process of the industrial estate.

MATERIALS AND METHODS

The Khorramabad Industrial Park is located in the southeast of Khorramabad city in Lorestan Province, Iran, with an area of 122 ha (Fig.1). There are more than 150 plants including food, chemicals, wood, rubber and plastics, non-metallic minerals, equipment, paper, metals, etc. factories. The rate of waste generation in this complex is about 6.5 tons which can be categorized as semi-municipal and industrial wastes. Waste management in Khorramabad industrial estate is very unsuitable. All of the waste is gathered with a trunk and open dumped near the park without any supervision.

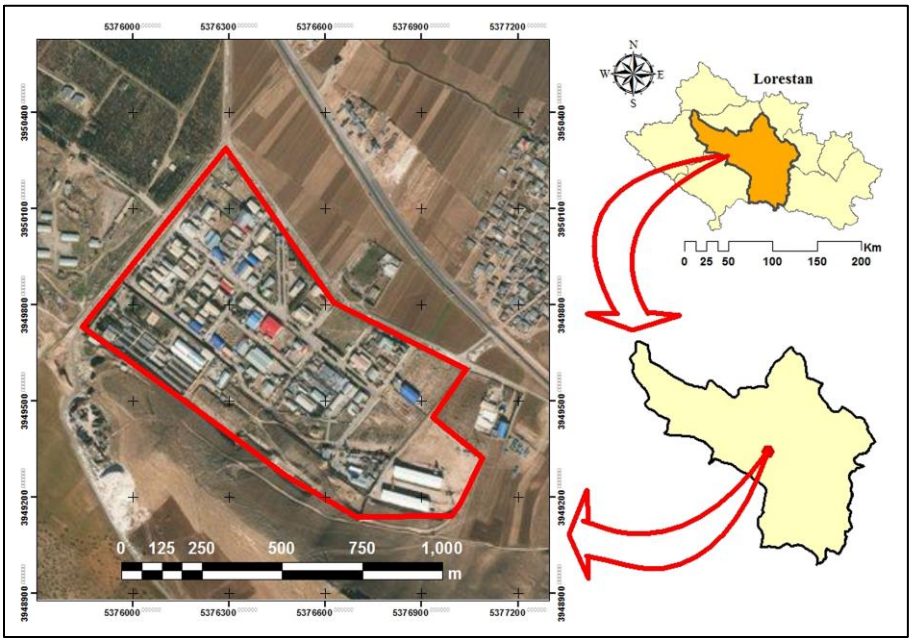

Fig. 1. The location of Khorramabad industrial park

The present study employs the fuzzy RIAM method to assess disposal scenarios for solid waste management of Khorramabad industrial park. Figure 2 shows the architecture of the proposed model. As for the employed system, the study makes use of Mamdani method of Fuzzy Inference System (FIS) (Yang et al., 2011), which was first proposed in 1975 by Mamdani and Baaklini (Mourhir et al., 2016; Givargis et al., 2018). The Fuzzy inference systems use if-then rules, which are very similar to people's thinking techniques (Estay-Ossandon et al., 2018). These rules are a set of linguistic variables that determine how the fuzzy inference system can make a choice regarding the definition of an input or output (Ahmadipari et al., 2018; Givargis et al., 2018). Both the inputs and outputs are crisp, whereas the knowledge base is in accordance to fuzzy rules and its ability to convert the real value of output and input to a linguistic parameter by means of membership functions (Ghobadi & Ahmadipari, 2018). Applying if-then fuzzy rules change the fuzzy input to fuzzy output.

Here, in order to define the rules of the proposed method, the RIAM model, being a method of Environmental Impact Assessment (EIA), was applied. As for defining the rules of the fuzzy method, disposal scenarios for industrial waste were assessed with an integrated model of Fuzzy and RIAM in a FIS. This entailed collecting, classifying, and scoring the assessment criteria for industrial waste, with the latter two being based on literature review, expert judgments, and engineering opinions. Finally, the results of this process were applied so that the rules in the proposed FIS could be defined.

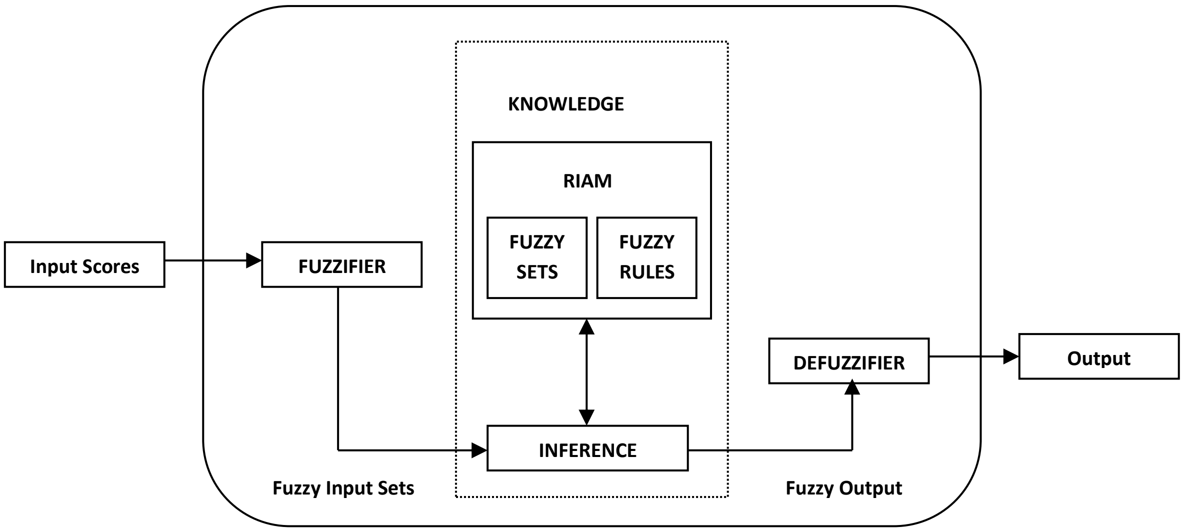

Fig. 2. The structure of proposed model for Fuzzy RIAM

Four solid waste management scenarios got selected for assessment in this study area: 1) Open dumping, 2) Sanitary landfill, 3) Gasification, and 4) Incineration.

Fuzzy RIAM method was implemented as follows: All factors for the assessment of disposal scenarios were collected by reviewing local conditions, previous studies, and experts' opinion. The model needs determining a specific assessment of the environmental factors through the process of scoping, and these factors will be in one of the following four classes: Physical-Chemical (PC), Biological-Ecological (BE), Sociological-Cultural (SC), and Economical-Operational (EO). Table 1 presents the environmental factors.

Table 1. The assessment criteria of disposal scenarios

Economical / Operational components	**Physical/Chemical components**
Costs of building a new landfill (EO1)	Current waste in industrial area (PC1)
Costs of current landfill expansion (EO2)	Generated leachate in the current landfill (PC2)
Leachate collection costs (EO3)	Collecting leachate, using drainage system (PC3)
Leachate treatment costs (EO4)	Discharge and reuse of leachate (PC4)
Costs of waste monitoring and analysis (EO5)	Discharging recycled leachate into municipal wastewater (PC5)
New land occupancy costs for the facilities (EO6)	Current situation of the facilities for recycling and refining (PC6)
Construction and operation costs of incinerators (EO7)	Leaching to ground water (PC7)
Waste Recycling costs (EO8)	Control and maintenance of the odor (PC8)
Costs of waste collection (gathering) (EO9)	GHG's emission and global warming potentiality (PC9)
Income from the products or produced energy (EO10)	Gas emission control and recycling methods (PC10)
	Processing of ash from industrial waste incineration (PC11)
Social/Cultural components	Biological/Ecological components
Impact on human settlements (SC1)	Impacts on groundwater through leachate seepage (BE1)
Dust problems for people (SC2)	Impacts on the soil (BE2)
Noise problems for people (SC3)	Impacts on the ecosystem (BE3)
People's participation in reusing the recycled materials (SC4)	Effects on decomposition of the wastes (BE4)
Creation of new jobs for local people (SC5)	Soil erosion, creation of excess runoff (BE5)
Odor problems for people (SC6)	Open dumping risks (BE6)

Afterwards, the criteria of the rapid matrix were determined in two main groups: “Group A” and “Group B”. Group A is of high importance for this method, as it can individually alter the calculated score. On the contrary, Group B is of relative importance, for it is unable to alter the calculated score (Aliakbari-Beidokhti et al., 2017). Table 2 shows assessment criteria of FRIAM method. The calculated score for each group is described through application of a series of math formulae. These rules allow the values for individual factors to be defined on a determined basis. The score of each group is calculated as follows (Pastakia & Jensen, 1998):

$$(A1)*(A2)=AT \quad (1)$$

$$(B1)+(B2)+(B3)=BT \quad (2)$$

$$(AT)*(BT) = ES \quad (3)$$

Where ES is the evaluation score of RIAM model.

Here, the current study employed fuzzy logic to not only have a score estimation but reduce the uncertainties. Table 3 presents fuzzy environmental scores to range bands. By applying the fuzzy set theory (FST) in the RIAM method, aspects of uncertainty in linguistic variables can be taken into consideration. Fuzzy RIAM is implemented in four stages:

- Determination of linguistic variables
- Definition of suitable membership functions
- Selection of the rules, in accordance with the knowledge base of the system
- Definition of an appropriate operator to integrate fuzzy sets

Fig 3 and 4 show the fuzzy module for input and output variables.

Table 2. Fuzzy assessment criteria of FRIAM method

Group	Criteria	Fuzzy scale	Description
(A) Criteria	A1 Importance of the condition	(3,4,5)	Important to national/international interest (A15)
		(2,3,4)	Important to regional/national interests (A14)
		(1,2,3)	Important to areas immediately outside the local condition (A13)
		(0,1,2)	Important only to the local condition (A12)
		(0,0,0)	No importance (A11)
	A2 Magnitude of change/effect	(2,3,4)	Major positive benefit (A23)
		(1,2,3)	Significant improvement in the status quo (A22)
		(0,1,2)	Improvement in the status quo (A21)
		(0,0,0)	No change of the status quo (A20)
		(0,1,2)	Negative change in the status quo (A24)
		(1,2,3)	Significant negative non-benefit or change (A25)
		(2,3,4)	Major non-benefit or change (A26)
(B) Criteria	B1 Permanence	(0,1,2)	No change/not applicable (B11)
		(1,2,3)	Temporary (B12)
		(2,3,4)	Permanent (B13)
	B2 Reversibility	(0,1,2)	No change/not applicable (B21)
		(1,2,3)	Reversible (B22)
		(2,3,4)	Irreversible (B23)
	B3 Cumulative	(0,1,2)	No change/not applicable (B31)
		(1,2,3)	Non-cumulative/single (B32
		(2,3,4)	Cumulative/synergistic (B33)

Table 3. Fuzzy environmental scores to range bands

Description	Fuzzy environmental scores	Range bands
Major positive	(0,0,108)	+E
Significant positive	(0,0,71)	+D
Moderately positive	(0,0,35)	+C
Positive	(0,0,18)	+B
Slightly positive	(0,0,9)	+A
No change	(0,0,0)	N
Slightly negative	(-9,0,0)	-A
Negative	(-18,0,0)	-B
Moderately negative	(-35,0,0)	-C
Significant negative	(-71,0,0)	-D
Major negative	(-108,0,0)	-E

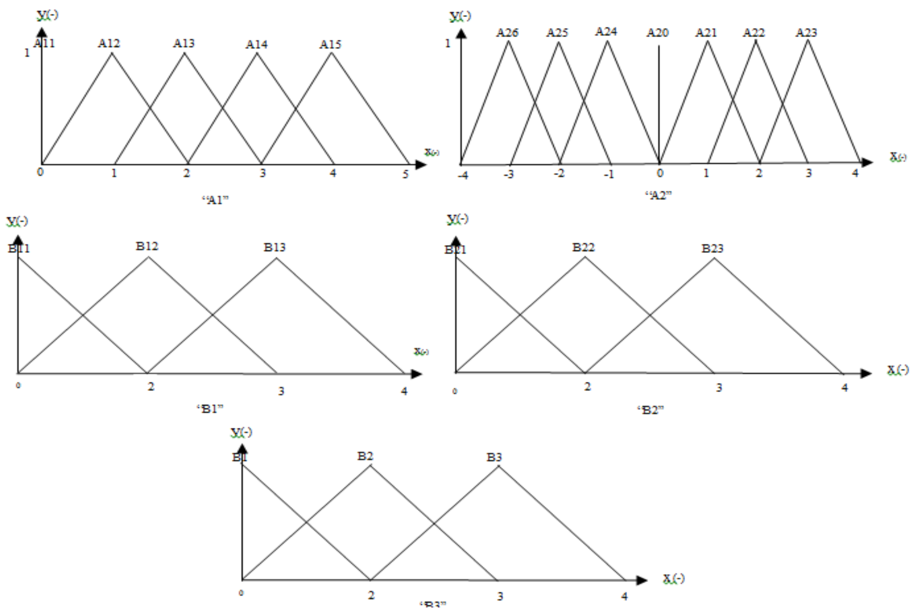

Fig. 3. The fuzzy module of input variables

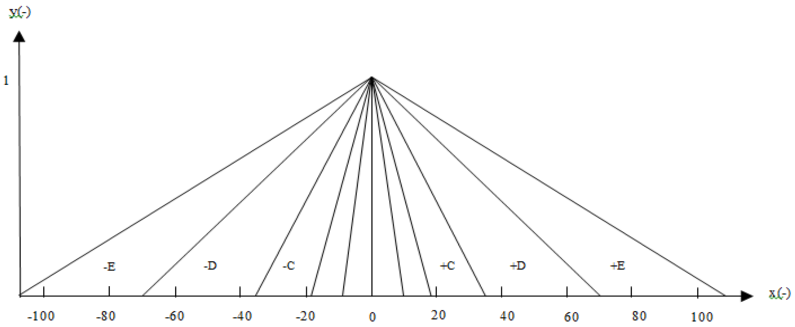

Fig. 4. The fuzzy module of output variables (RB)

RESULTS AND DISCUSSION

Table 4 presents the results of the Fuzzy RIAM Model, showing the environmental scores of the Fuzzy RIAM Method for all scenarios.

First scenario; open dumping

Results of Fuzzy RIAM for scenario 1 reveal that most of the impacts were negative (72.7%), as shown in Fig. 5. They also show very negative impacts on the different sections of the environment. This scenario is not a proper method, for the wastes are discharged into the nature and leachate affects water bodies including surface water and groundwater. Also, scenario 1 makes unpleasant odor and affects public health. On the other hand, open dumping is not financially advantageous (Panhwar et al., 2019). This scenario is only partially suitable for wastes that is not biodegradable and recyclable (Samal et al., 2020). Open dumping threatens the health and safety of the residents living around it. It is also against the law.

Table 4. The results of Fuzzy RIAM in Khorramabad

Components	Fuzzy weights (a,b,c)												Final weights			
Physical/Chemical	**Open dumping**			**Sanitary Landfill**			**Gasification**			**Incineration**			**S1**	**S2**	**S3**	**S4**
PC1	-60	-14	0	-40	-7	0	-72	-18	0	-120	-42	-8	-0.870	-0.528	-0.934	-0.470
PC2	-90	-28	-4	-40	-7	0	-36	-6	0	-144	-54	-12	-0.667	-0.528	-0.468	-0.377
PC3	0	8	42	0	14	60	-108	-36	-6	6	36	108	0.569	0.870	-0.537	0.537
PC4	-108	-36	-6	0	14	60	-48	-10	0	0	18	72	-0.537	0.870	-0.669	0.934
PC5	0	9	48	10	48	132	-90	-28	-4	0	12	54	0.647	0.418	-0.667	0.769
PC6	-96	-30	-4	0	12	54	0	6	36	-81	-24	-3	-0.625	0.769	0.468	-0.760
PC7	-144	-54	-12	-96	-27	0	-192	-81	-24	-192	-81	-24	-0.377	-0.669	-0.262	-0.262
PC8	0	6	36	0	14	60	-120	-42	-8	0	16	66	0.468	0.870	-0.470	0.970
PC9	-144	-54	-12	-96	-27	0	-192	-81	-24	-192	-81	-24	-0.377	-0.669	-0.262	-0.262
PC10	-96	-27	0	24	81	192	8	42	120	0	14	60	-0.669	0.262	0.470	0.870
PC11	0	6	36	5	32	99	0	12	54	-192	-81	-24	0.468	0.619	0.769	-0.262
Biological/Ecological	Open dumping			Sanitary Landfill			Gasification			Incineration			S1	S2	S3	S4
BE1	-108	-36	-6	-80	-21	0	-192	-81	-24	-144	-54	-12	-0.537	-0.825	-0.262	-0.377
BE2	-144	-54	-12	-96	-27	0	-144	-54	-12	-108	-36	-6	-0.377	-0.669	-0.377	-0.537
BE3	-144	-54	-12	-66	-16	0	-99	-32	-5	-108	-36	-6	-0.377	-0.970	-0.595	-0.537
BE4	-72	-18	0	0	12	54	-176	-72	-20	-108	-36	-6	-0.934	0.769	-0.292	-0.537
BE5	-40	-7	0	-54	-12	0	-192	-81	-24	-108	-36	-6	-0.528	-0.769	-0.262	-0.537
BE6	-108	-36	-6	-54	-12	0	-120	-42	-8	-144	-54	-12	-0.537	-0.769	-0.470	-0.377
Social/Cultural	Open dumping			Sanitary Landfill			Gasification			Incineration			S1	S2	S3	S4
SC1	-60	-14	0	0	14	60	-108	-36	-6	-108	-36	-6	-0.870	0.870	-0.537	-0.537
SC2	-54	-12	0	0	14	60	-36	-6	0	-108	-36	-6	-0.769	0.870	-0.468	-0.537
SC2	-60	-14	0	0	7	40	-72	-20	-2	-72	-18	0	-0.870	0.528	-0.882	-0.934
SC3	0	14	60	0	6	36	-54	-12	0	0	6	36	0.870	0.468	-0.769	0.468
SC4	-80	-21	0	0	14	60	0	12	54	0	6	36	-0.825	0.870	0.769	0.468
SC5	-108	-36	-6	4	28	90	-120	-42	-8	-108	-36	-6	-0.537	0.667	-0.470	-0.537
Economical Operational	Open dumping			Sanitary Landfill			Gasification			Incineration			S1	S2	S3	S4
EO1	-54	-12	0	0	3	24	-108	-36	-6	-99	-32	-5	-0.769	0.290	-0.537	-0.595
EO2	-54	-12	0	0	16	66	-108	-36	-6	-44	-8	0	-0.769	0.970	-0.537	-0.587
EO3	-72	-18	0	0	3	24	-132	-48	-10	-40	-7	0	-0.934	0.290	-0.418	-0.528
EO4	-28	-4	0	0	16	66	-99	-32	-5	-72	-18	0	-0.349	0.970	-0.595	-0.934
EO5	0	12	54	-48	-9	0	-99	-32	-5	-60	-14	0	0.769	-0.647	-0.595	-0.870
EO6	-108	-36	-6	-36	-6	0	-36	-6	0	-108	-36	-6	-0.537	-0.468	-0.468	-0.537
EO7	0	16	66	0	7	40	-40	-7	0	-108	-36	-6	0.970	0.528	-0.528	-0.537
EO8	0	12	54	0	7	40	-108	-36	-6	-36	-6	0	0.769	0.528	-0.537	-0.468
EO9	-36	-6	0	0	7	40	-66	-16	0	-36	-6	0	-0.468	0.528	-0.970	-0.468
EO10	0	6	36	0	14	60	0	14	60	9	24	27	0.468	0.870	0.870	0.871

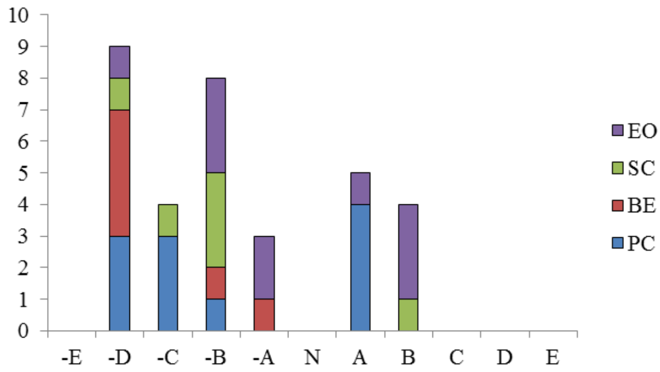

Fig. 5. Assessment result of the first scenario

Second scenario; Sanitary Landfill

Fig. 6 illustrates the assessment result of the second scenario. The positive impacts of this scenario (65.6%) are higher than scenario 1. These positive impacts are because of reduced amount of the leachate, less odors, lower contamination of underground water and soil, less toxic gas emissions, less infection by insects and birds, and reduced risk of explosion at the disposal site. Purified leachate water can be employed to make a landscape at the site of landfills. Landfill gas could be utilized as fuel to compensate for landfill costs (Naveen & Malik, 2019). It is very clear that the landfill should evolve not only to minimize the potential risks and environmental burden of landfills but to re-introduce the buried resources to the material cycle. Landfill reduces the emission and potential pollution of wastes, detaining the pollutants contained in it (Deus et al., 2020).

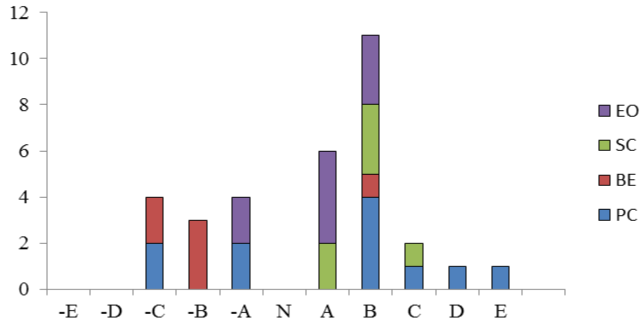

Fig. 6. Assessment result of the second scenario

Third scenario; Gasification

Fig. 7 illustrates the assessment result of the third scenario, which has many negative effects (82.9%), with the most important positive impact of this method being its production of no hazardous gas. As for its negative points, it needs regular maintenance and cleaning of the system. It also ends up with releasing chemicals that are toxic to vegetation and soil. One major problem is the inadequacy of waste with this scenario that economically decreases the efficiency of the process. Also, the regional regulations make some limitations to this scenario. For instance, the produced fuel can be neither sold nor used. All fuels have to undergo quality control and must be transported under the National Iranian Oil Company supervision. It should also be mentioned that the negative impacts are not only for economical components. Obviously, the operation of gasification damages the physical and biological components as well (Tavares et al., 2019). Furthermore, social acceptance possibly drops due to some limitations.

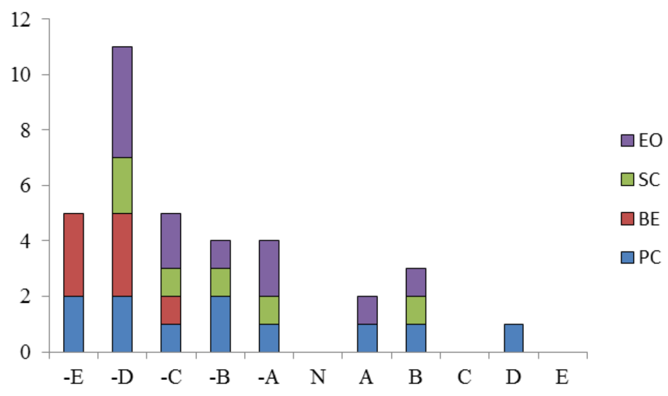

Fig. 7. Assessment result of the third scenario

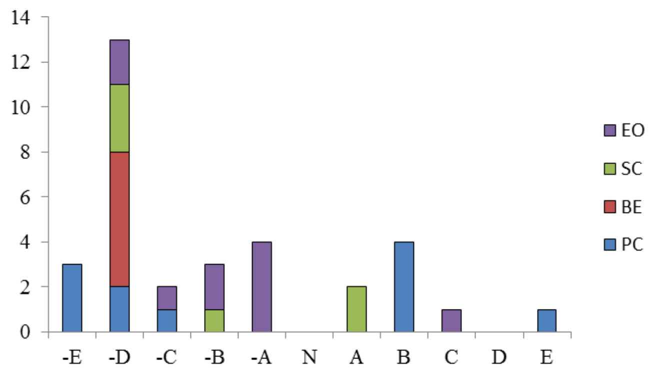

Fig. 8. Assessment result of the fourth scenario

Fourth scenario; Incineration

Finally, Fig. 8 illustrates the result of the fourth scenario. The negative effects of this scenario are 75.8%. This scenario has the greatest impact on air pollution. The pollution induced by this scenario is mainly caused by NO2, SO2, and NOx Particles, which have negative impacts (including physical, chemical, biological, ecological, and sociological) on human health. The most important positive effect of incineration is its reduction of the waste volume, which may reduce the problem of waste accumulation (Silva et al., 2019). This scenario has undesired impacts on residential areas in the vicinity of the disposal site, leading also to many problems like noise pollution, dust, and waste stink in the social/cultural section. Incineration has undesired impacts on the economic/operational sector as well, probably due to the fact that the incinerators, by themselves, require lots of equipment and maintenance.

CONCLUSION

The Fuzzy RIAM was employed for industrial waste management of Khorramabad in order to assess the impacts of the four different scenarios, namely, open dumping, sanitary landfill, gasification, and incineration. To do so, Fuzzy RIAM, a very useful and rapid model to determine the effects of these scenarios, was applied. The obtained results of this study made it obvious that among all assessed scenarios, open dumping had the most negative impacts, since in this scenario, the wastes are discharged to nature and leachate influences water bodies including surface water and groundwater, making unpleasant odors, and affecting the public health in a negative way. Also, open dumping is not financially advantageous. Results also showed that the second scenario was more preferred than the other three proposed scenarios, having the most positive effects. The percentages of positive and negative effects for sanitary landfill, gasification, and incineration, were (+65.6% and -34.4%), (+17.1% and -82.9%), and (+24.2% and -75.8%), respectively. Hoveidi et al. (2013) implemented RIAM method for waste management in Toos industrial estate in Mashhad. They considered various disposal options such as open dumping, sanitary landfill, gasification and incineration. Their results showed that sanitary landfill led to more beneficial effects than other four options. Similarly, results of environmental impact assessment based on RIAM model, carried out by Kumar et al. (2013) in Nunna landfill in Vijayawada, India, as well as Aliakbari-Beidokhti et al. (2017) in Mashhad landfill, Iran, demonstrated that the sanitary landfill scenario was the best scenario for the disposal site. According to the results of Shayesteh et al. (2020), recycling and sanitary landfill were in the first priority to be used in a disposal site and reduce the pollution. In this study, replacing the fuzzy calculation instead of crisp calculations sharply improved the RIAM technique, based on the concepts of the calculation process and human judgment errors. In addition, the uncertainty factor was covered in this approach. It is noteworthy that methods like Fuzzy RIAM in Iran, a developing country without the suitable infrastructure for costly evaluations of the development plans, are very effective and useful. Thus, the current research made it obvious that FRIAM could completely assess the weaknesses and strengths of each of the four proposed scenarios in both practical and theoretical terms. It is understood that all factors of the environment were assessed in terms of the negative and positive impacts of each alternative. Therefore, the study introduced a fuzzy assessment tool for EIA of disposal scenarios, which could help industrial managers and planners of Khorramabad, also the decision-makers in this field, to be perfectly clear and understandable. FRIAM allows reanalysis and in-depth analysis of selected components in a rapid and accurate method.

GRANT SUPPORT DETAILS

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests 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 has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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