Environ Geol (2005) 47: 632–639
DOI 10.1007/s00254-004-1188-8

ORIGINAL ARTICLE

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Environmental impact assessment using rapid impact assessment matrix (RIAM) for Russeifa landfill, Jordan

Received: 23 June 2004
Accepted: 21 September 2004
Published online: 25 November 2004

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Abstract An environmental impact assessment (EIA) study for the solid waste landfill was prepared for the Russeifa area, northeast Jordan. As landfill was not subjected to sophisticated EIA, serious environmental problems are still occurring, such as groundwater contamination and air pollution. Three alternatives were proposed to rehabilitate the landfill: upgrading the existing landfill, construction of a biogas plant and its relocation. The EIA for the three options was carried out using the rapid impact assessment matrix (RIAM), it applies a consistent and recordable assessment of the importance of the different components. The scoping components included in the RIAM were: physical/chemical, biological/ecological, social/cultural and economic/operational components. The RIAM analysis showed that the least negative impacts would be to relocate to a better-managed sanitary landfill. The most serious negative impacts were the contamination of groundwater, air pollution and public health. These impacts can be mitigated through a comprehensive environmental management plan for the Russeifa landfill to address the deterioration of environmental components in the vicinity of landfill.

Keywords Environmental impact assessment · Solid waste · Russeifa Landfill · RIAM · Biogas plant · Jordan

Introduction

A domestic solid waste landfill causes major negative environmental impacts if not managed in a proper manner. In Jordan the number of domestic solid waste landfills has increased to 24 in different cities and municipalities. Some have a direct negative impact on the environment and public. There is a public demand to avoid these environmental problems at future landfill sites. Environmental impact assessments(EIAs) are required by the international and national authorities for new established projects (World Bank 1988; DANIDA 1994).

Environmental impact assessments can be defined as the systematic identification and evaluation of the potential impacts of proposed projects, plans, programs, or legislative actions relative to the physical, chemical, biological, cultural, and socio-economic components of the total environment. The prime purpose of the EIA process is to encourage the consideration of the environment in planning and decision-making to ultimately arrive at actions that are more compatible with the environment (Canter 1996). EIA is an environmental management tool aiming at identifying environmental problems and providing solutions to prevent or minimize these problems to the accepted levels. It also provides an environmental management plan, which includes a monitoring program (Gilpin 1995).

The safe and reliable long-term disposal of solid waste is an important component of integrated waste management. Historically, landfills have been the most common, environmentally and economically acceptable method of disposal of solid waste. Even with the implementation of waste reduction, recycling, and

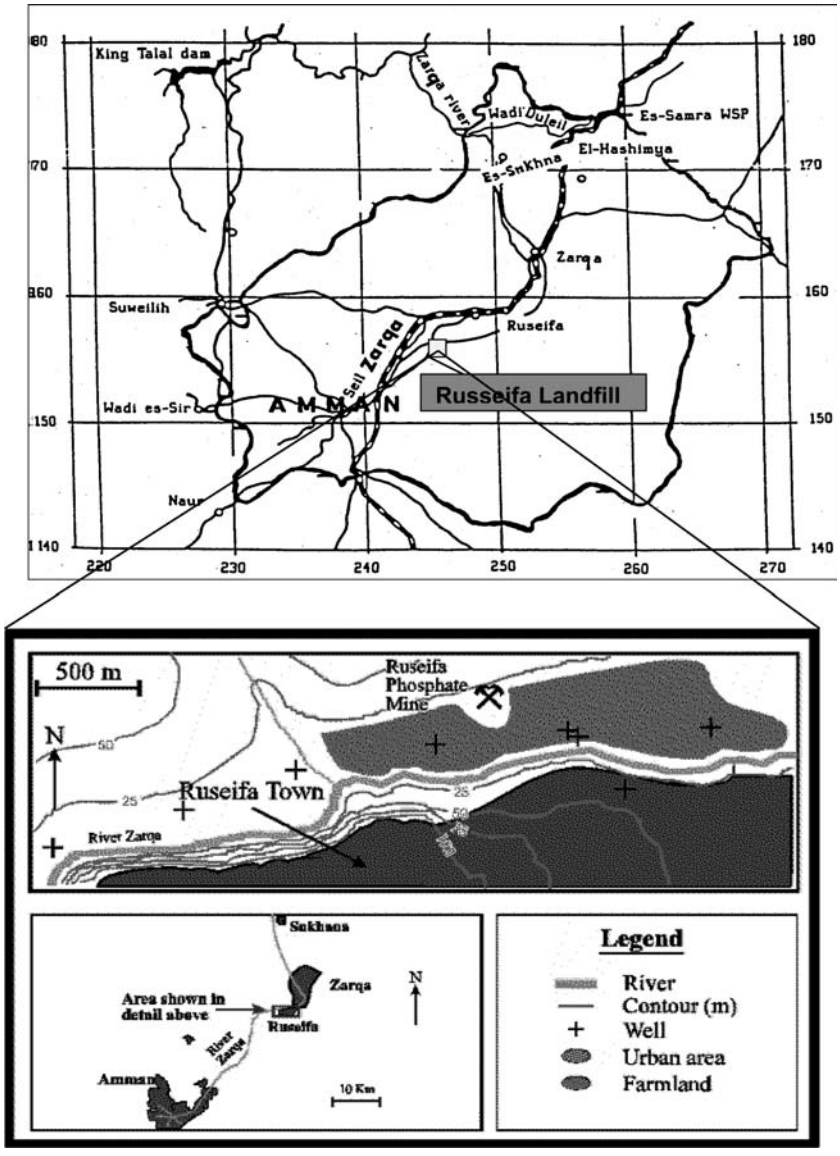


Fig. 1 Location map of the Russeifa landfill, Jordan

transformation technologies, disposal of solid waste in landfills remains a significant component of an integrated waste management strategy (Tchobanoglous et al. 1993).

EIA Jordanian draft guidelines identify the types of EIA required for any project and categorize the projects into three classes as follows: Class A projects, which require full or comprehensive environmental impact assessment where domestic solid waste landfill projects are within this class. Class B projects, these projects are not clear if an EIA is needed or not. Therefore, limited EIA study is required to understand the interactions between projects and the environment to be able to decide if comprehensive EIA study is needed or the limited EIA study is enough. Class C projects, EIA is not required for projects within this category.

The objective of this study is to assess the EIA of Russeifa landfill on the environment and to propose alternatives (options) to the existing landfill. The proposed options are to include the upgrading of the existing landfill, construction of a biogas plant, and relocation of the landfill. The rapid impact assessment matrix(RIAM) was used to compare these options. This method was developed as a holistic and reproducible method suitable to compare and identify major impacts of different options of a project, plan, etc. (Pastakia 1998).

Table 1 Environmental impacts of option no.1 (upgrading of existing landfill)

	Components	ES	RB	A1	A2	B1	B2	B3
Physical and chemical components (PC)								
PC1	Odours and gaseous emissions	−81	−E	3	−3	3	3	3
PC2	Groundwater pollution	−81	−E	3	−3	3	3	3
PC3	Dust	−24	−C	2	−2	2	2	2
PC4	Noise	0	N	1	0	2	2	2
PC5	Air pollution	−81	−E	3	−3	3	3	3
PC6	Impacts from increased industrial activity	−108	−E	4	−3	3	3	3
Biological and ecological components (BE)								
BE1	Impacts on biota	−6	−A	1	−1	2	2	2
BE2	Damage of habitats	−9	−A	1	−1	3	3	3
BE3	Aesthetic impact	−9	−A	1	−1	3	3	3
BE4	Littering	−18	−B	2	−1	3	3	3
Sociological and cultural components (SC)								
SC1	Public acceptability	−42	−D	3	−2	2	2	3
SC2	Work opportunity	12	B	2	1	2	2	2
SC3	Public health	−81	−E	3	−3	3	3	3
SC4	Impacts on housing	−54	−D	3	−2	3	3	3
SC5	Population growth	−12	−B	2	−1	2	2	2
SC6	Public safety	−18	−B	2	−1	3	3	3
Economical and operational components (EO)								
EO1	Operation and maintenance cost	−24	−C	2	−2	2	2	2
EO2	Recycling	42	D	2	3	2	2	3
EO3	Traffic	0	N	2	0	2	2	3
EO4	Property value loss	−12	−B	1	−2	2	2	2
EO5	Health costs to community	−12	−B	1	−2	2	2	2

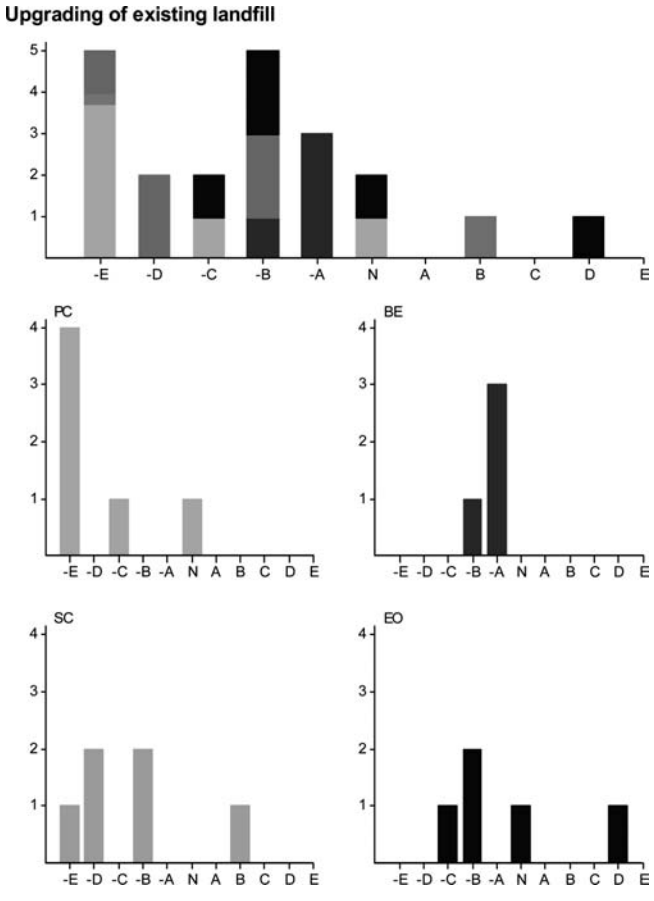
Summary of scores

Range	−108–72	−71–36	−35–19	−18–10	−9–1	0–0	1–9	10–18	19–35	36–71	72–108
Class	−E	−D	−C	−B	−A	N	A	B	C	D	E
PC	4	0	1	0	0	1	0	0	0	0	0
BE	0	0	0	1	3	0	0	0	0	0	0
SC	1	2	0	2	0	0	0	1	0	0	0
EO	0	0	1	2	0	1	0	0	0	1	0
Total	5	2	2	5	3	2	0	1	0	1	0

Environmental impact assessment stages

The comprehensive EIA study normally consists of the following stages:

- Screening program: it is the responsibility of the regulatory authority to identify the need and the type of EIA required for the proposed project.
- Scope: this stage is one of the most important stages of the EIA study, as different stakeholders (public, non-governmental organizations (NGOs), local communities and relevant regulatory authorities) participate in this stage to obtain the following output. Project interactions with key environmental issues to be included in the EIA study, the boundaries of these issues, the legal requirements and the finalized term of references.
- Assessment: selected key environmental issues should be evaluated according to specified assessment methods such as mathematical modeling, metrics, and professional judgment. Significant criteria should be established at this stage for impact evaluations (direct/indirect, extent, duration, frequency, reversibility, and level of significant impact). Also the roots of impact should be understood in this stage to be able to intercept and mitigate them in the next stage.
- Mitigation measures: all significant key environmental issues resulting from the above stage should be mitigated to prevent or minimize their impacts on the environment. An environmental management plan should be produced from this stage to handle environmental affairs throughout the project life.
- Monitoring: there are two types of monitoring; compliance monitoring conducted by the regulatory authorities to ensure compliance of project environmental activities with local regulations, and internal monitoring carried out by the project proponent to monitor the effectiveness of the mitigation measures proposed by the EIA studies and its capabilities to meet local requirements.
- Reporting: the findings of the study should be prepared in a report according to the term of references



and submitted to the regulatory authority for review and approval.
- Reviewing: the submitted reports shall be reviewed against the finalized term of references by the regulatory authority before approval.

General description of Russeifa landfill

The Russeifa solid waste landfill is the largest landfill in Jordan, near Russeifa city, which lies 15 km to the northeast of Amman (Fig. 1). The area of the landfill is about 1.2 km^2 and was commissioned in 1986. This landfill serves about 2.5 million inhabitants living in Amman, Zarqa and Russeifa areas and receives more than half of the solid waste in Jordan, which accounts for 2,200 tons/day (Chopra et al. 2001).

The elevation of the landfill is about 660 m above sea level. To the north of the site there are many groundwater wells distributed around the landfill. Underground water that forms part of the Amman–Zarqa Basin lies 30–50 m below the site. The landfill is not lined, and has a compacted clay and sand bottom. There is no subsurface drainage system to collect the leachate, so the leachate goes directly to the groundwater, hence, the water depth at the landfill does not exceed 30 m. There is also a liquid waste disposal site, which is located near the landfill, where the liquid waste comprises untreated industrial wastewater and cesspools wastewater. The leachate from this area is highly contaminated, causing pronounced spatial variability in leachate composition throughout the landfill area. The disposal method practiced at Russeifa site is known as the sandwich method in which the solid waste is dumped followed directly by at least 30 cm of compacted earth material.

The Russeifa landfill receives 75% of Jordan solid waste. The amount of solid waste to the site is about 2,100 ton/day, based on 0.93 kg/capita/day. The composition of the solid waste is: organic household waste 53%; paper 17%; metals 8%; glass 10% and plastic 12% (Chopra et al. 2001).

As with the other existing landfills in Jordan, Russeifa landfill was not subjected to a sophisticated EIA. Consequently, the environment and the quality of life in the area was affected by the existing landfill. If the existing conditions prevail, further environmental deterioration will be continued.

Environmental management plan for Russeifa landfill

The environmental management plan for the Russeifa landfill may primarily address the deterioration of environmental components by the landfill itself. The three alternatives mentioned previously were proposed to alleviate the degradation of environmental quality. The existing landfill is a major source of offensive odor and fumes generated from spontaneous gas emissions due to biological degradation of the wastes. Also, it is a good breeding ground for insects and rodents and the generated leachate, which is the major source for groundwater contamination. The upgrading of the existing landfill is the first alternative which can be achieved by adopting the following measures: (1) the bottom of the site should be lined with an impervious layer to prevent leachate seepage to the groundwater, (2) monitoring to control the input to prevent the entry of hazardous wastes and liquid industrial wastes, (3) monitoring facilities for quality of air and the gaseous emissions, (4) set-up collection system for the leachate to prevent groundwater contamination, (5) establishing a biogas plant, (6) providing sorting facilities to enhance recycling, (7) establishing a program for the control and elimination of insects and rodents, and (8) planting the surrounding area of the landfill with suitable trees.

The second alternative is the construction of a biogas plant on a fenced area of about 400,000 m^2 at a distance not less than 5 km from the city of the Zarqa. It will process 1,200 ton/day of organic solid waste by appro-

Table 2 Environmental impacts of option no.2 (construction of biogas plant)

	Components	ES	RB	A1	A2	B1	B2	B3
Physical and chemical components (PC)								
PC1	Odors and gaseous emissions	−36	−D	2	−2	3	3	3
PC2	Groundwater pollution	−36	−D	2	−2	3	3	3
PC3	Dust	−6	−A	1	−1	2	2	2
PC4	Noise	−42	−D	3	−2	2	3	2
PC5	Air pollution	−108	−E	4	−3	3	3	3
PC6	Impacts from increased industrial activity	−15	−B	1	−3	1	1	3
Biological and ecological components (BE)								
BE1	Impacts on biota	−5	−A	1	−1	2	2	1
BE2	Damage of habitats	−27	−C	3	−1	3	3	3
BE3	Aesthetic impact	−27	−C	3	−1	3	3	3
BE4	Littering	−36	−D	2	−2	3	3	3
Sociological and cultural components (SC)								
SC1	Public acceptability	−12	−B	2	−1	2	2	2
SC2	Work opportunity	56	D	4	2	3	2	2
SC3	Public health	−54	−D	2	−3	3	3	3
SC4	Impacts on housing	−32	−C	2	−2	3	2	3
SC5	Population growth	−7	−A	1	−1	2	2	3
SC6	Public safety	−16	−B	2	−1	2	3	3
Economical and operational components (EO)								
EO1	Operation and maintenance cost	−56	−D	4	−2	3	2	2
EO2	Recycling	42	D	2	3	3	2	2
EO3	Traffic	−42	−D	3	−2	3	2	2
EO4	Property value loss	−4	−A	1	−1	2	1	1
EO5	Health cost to community	−5	−A	1	−1	2	1	2

Summary of scores

Range	−108–72	−71–36	−35–19	−18–10	−9–1	0–0	1–9	10–18	19–35	36–71	72–108
Class	−E	−D	−C	−B	−A	N	A	B	C	D	E
PC	1	3	0	1	1	0	0	0	0	0	0
BE	0	1	2	0	1	0	0	0	0	0	0
SC	0	1	1	2	1	0	0	0	0	1	0
EO	0	2	0	0	2	0	0	0	0	1	0
Total	1	7	3	3	5	0	0	0	0	2	0

priate recycling processes as well as dumping the remainder in the sanitary landfill.

The third alternative is to establish a new landfill on a fenced area of 1,000,000 m^2 towards the east of the existing landfill to handle about 2,400 ton/day of solid waste of which around 50% is organic. The new landfill should be lined and have a collection and treatment system for leachate.

In evaluating the positive and negative impacts of each of the proposed alternatives, those related to the existing landfill were taken as a reference base and magnitudes of the impacts of the proposed alternatives accordingly.

Methodology of EIA

The EIA is carried out using a rapid environmental impact matrix method (Pastakia 1998; Pastakia and Madsen 1996). This methodology is used to provide an assessment of possible environmental impacts of the landfill on the environment. The RIAM is a scoring impact of components against pre-defined criteria, and transposing scores into ranges describing the degree of positive or negative impacts. Each component is evaluated against each criteria and the value recorded in the matrix. In this instance, the RIAM used the following assessment criteria: importance (A1), magnitude (A2), permanence (B1), reversibility (B2), and cumulation (B3). Using the RIAM formula, the score for each component is then derived (Pastakia 1998).

Scores for the value criteria (group (B)) are added together to provide a single sum. This ensures that the individual value scores cannot influence the overall score, but that the collective importance of all values (group (B)) are fully taken into account. The sum of the group (B) scores is then multiplied by the result of the group (A) scores to provide a final assessment score (ES) for the condition. The formula used to compute the ES can be expressed as follows:

$$ES = (A1 \times A2 \times \cdots AN) \times (B1 + B2 + \cdots BN)$$

where (A1) is the individual criteria scores for group (A), B1 is the individual criteria scores for group (B), and the ES is the assessment score for the condition.

To investigate the impact assessment of landfill, the study focused on four primary fields of concern. The physical/chemical(pc) components were restricted to those that related to the changes in the quality of groundwater and air pollutants that cause degradation to the environment. Biological/ecological(BE) components reflected changes that might occur with respect to fauna and flora and aesthetics. The sociological/cultural(SC) components are concerned with the effect of the landfill on the public health and safety of the people living in the areas surrounding the landfill, in addition to the impacts on housing. The economical/operational(EO) components deal with those impacts related to the management mechanism of solid wastes, maintenance, and operation of landfill facilities.

Environmental assessment using RIAM

The EIA of the Russeifa landfill is carried out using the RIAM computer package (Srensen et al. 1998), in which three alternatives were considered. The RIAM program allows these alternatives (options) to be incorporated in accordance with the principles of the RIAM concept.

The first step in the RIAM is to set up a number of different options for the assessment in question, and the RIAM program will individually process these, as in this case three options were considered: (1) upgrading the existing landfill, (2) construction of a biogas plant, and (3) relocation of the landfill. These options should be saved in the program. Then, the component screen records the results of the scoping of the assessment. All four types of components in the RIAM system are catered, and each component is individually coded. The component list displays all the elected components for each option. Under these components RIAM allows automatic recording of the criteria values given by the user for each component. The scales for each cell are displayed to allow rapid and easy checking of attributed values. After completing the RIAM analysis, the RIAM report shows the actual values attributed to each component, as well as a summary of the scores. Moreover, from the RIAM report it is possible to view the result of the analysis as a histogram for each option and corresponding components. The ranges were not expressed as ± 5, but as $\pm$A to E (with *N* representing the zero range). The histograms provide comparative pictures of positive/negative impacts between options, to identify important negative components.

The following components are introduced in the present study: six components of PC, four components of BE, six components of SC, and five components of OP.

Table 1 summarizes the scoping components and the results of the RIAM in a matrix form for the Option No. 1. Accordingly, these matrices are represented graphically by histograms as in Fig. 2. As shown in Fig. 2, the majority of the PC components are classified as major negative impacts including groundwater contamination, air pollution (i.e., odors and gas emissions, dust), and noise pollution. The slightly negative and negative impacts encompass the effect of landfill on biota and degradation of aesthetics. The SC impacts are classified as negative to major negative impacts due to their effect on the health of people living close to the landfill. Only positive benefits of this option are associated with the work opportunities and recycling process of wastes.

Table 2 summarizes the matrices of RIAM results for the Option No. 2, and Fig. 3 shows these results in graphical histograms. As shown in Fig. 3, a variety of environmental issues have been enhanced and improved. Improvements were seen by reduction of some PC impacts such as odor, gaseous emissions, groundwater pollution and air pollution. Most of the PC and BE

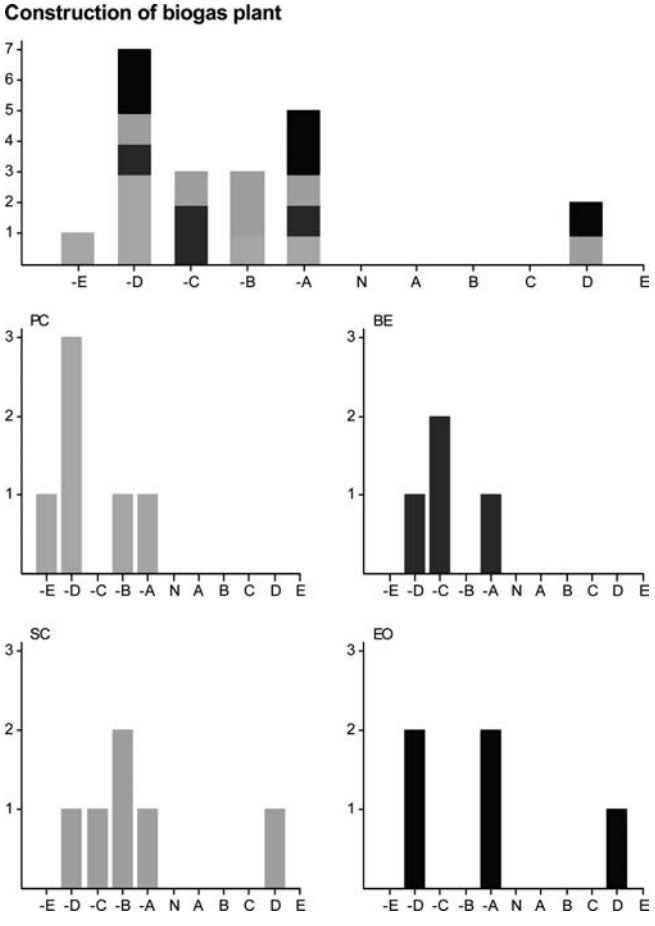


Table 3 Environmental impacts of option no.3 (relocation of landfill)

	Components	ES	RB	A1	A2	B1	B2	B3
Physical and chemical components (PC)								
PC1	Odors and gaseous emissions	−6	−A	1	−1	2	2	2
PC2	groundwater pollution	−6	−A	1	−1	2	2	2
PC3	Dust	0	N	1	0	2	3	2
PC4	Noise	0	N	1	0	2	2	2
PC5	Air Pollution	−7	−A	1	−1	2	3	2
PC6	Impacts from increased industrial activity	−12	−B	2	−1	2	2	2
Biological and ecological components (BE)								
BE1	Impacts on biota	−6	−A	1	−1	2	2	2
BE2	damage of habitats	−12	−B	1	−2	2	2	2
BE3	Aesthetics impact	−6	−A	1	−1	2	2	2
BE4	Littering	−6	−A	1	−1	2	2	2
Sociological and cultural components (SC)								
SC1	Public acceptability	−6	−A	1	−1	2	2	2
SC2	work opportunity	12	B	2	1	2	2	2
SC3	Public health	−6	−A	1	−1	2	2	2
SC4	impact on housing	−6	−A	1	−1	2	2	2
SC5	Population growth	−5	−A	1	−1	2	1	2
SC6	Public safety	−12	−B	2	−1	2	2	2
Economical and operational components (EO)								
EO1	Operation and maintanance	−5	−A	1	−1	2	1	2
EO2	Recycling	36	D	2	3	2	2	2
EO3	Traffic	−6	−A	1	−1	2	2	2
EO4	Property value loss	−6	−A	1	−1	2	2	2
EO5	Health costs to community	−6	−A	1	−1	2	2	2

Summary of scores

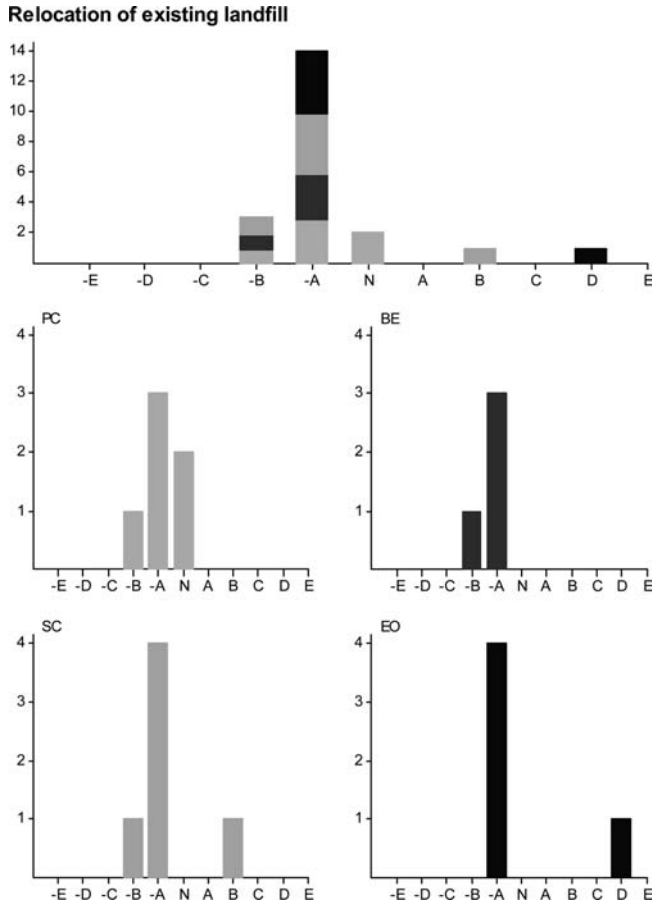
Range	−108–72	−71–36	−35–19	−18–10	−9–1	0–0	1–9	10–18	19–35	36–71	72–108
Class	−E	−D	−C	−B	−A	N	A	B	C	D	E
PC	0	0	0	1	3	2	0	0	0	0	0
BE	0	0	0	1	3	0	0	0	0	0	0
SC	0	0	0	1	4	0	0	1	0	0	0
EO	0	0	0	0	4	0	0	0	0	1	0
Total	0	0	0	3	14	2	0	1	0	1	0

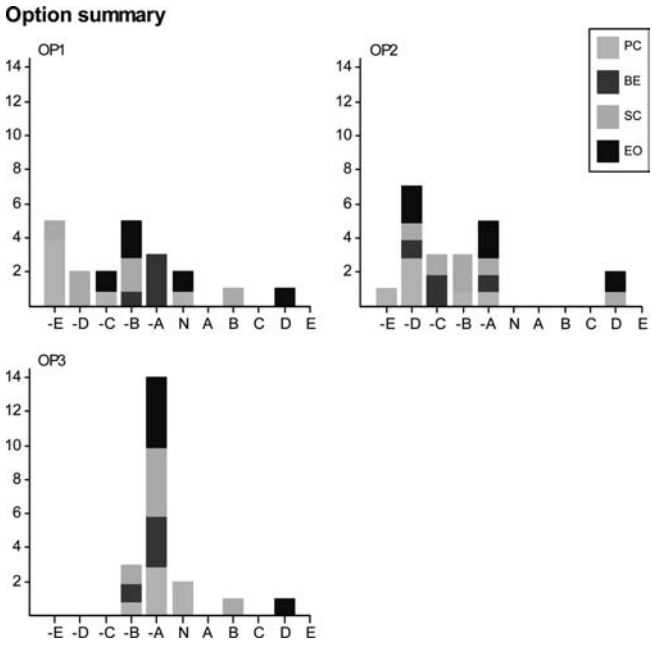
impacts are classified as slightly negative to significantly negative impacts. Some improvement to the quality of environment was expected in the long-term. EO impacts were seen to be generally positive. The conclusion for this option is that the construction of a biogas plant would improve and reduce the negative impacts of the landfill on the environment and on the local people. However, the costs associated with mitigation of these negative impacts and the operations and maintenance requirements could be relatively high.

Table 3 summarizes the RIAM analysis for Option No. 3 and Fig. 4 shows the impact components through graphical histograms. This option also shows some improvements over Option No. 2, but some of the negative impacts of PC components were reduced and/or improved. They were falling within the slightly negative to negative impact range. This reflects the possible mitigation of some environmental problems such as groundwater contamination, due to the fact that the new landfill will be lined and have leachate collection and a treatment system to prevent any seepages to groundwater. Furthermore, the location of the new landfill will be far away from the inhabited areas, so its effect on the people health might be limited. The positive issues of this option were associated with recycling and construction of sorting and monitoring facilities.

Conclusions

The EIA of the Russeifa landfill was carried out to evaluate the impacts of three different alternatives (options) of the existing landfill which are: upgrading the existing landfill, construction of a biogas plant and the relocation of the landfill, i.e. construction of a new sanitary landfill. The RIAM is an effective and rapid method to demonstrate the impact between these options. The matrices and the histograms of RIAM results provide a comparative picture of the positive/negative impacts between the three options and identify the most





important negative components. The most negative impacts of the existing landfill were the groundwater contamination, air pollution and public health. These impacts were classified as major negative impacts in option no. 1 and reduced to moderate negative impacts in option no. 2 and slightly negative in option no. 3.

Figure 5, illustrates the histograms of the results of RIAM analysis of the three options to simplify the comparison between these options. From Fig. 5, it can be concluded that the best option which has the minimum negative environmental impact is the relocation of the landfill towards the east of the existing landfill and construction of a new landfill which is properly engineering designed to cope with any negative environmental impacts that might affect the environmental components in the area. However, this will increase the operation and maintenance cost, which is unavoidable.

Acknowledgements The author expresses his sincere thanks to Mrs. Manal Khudeir for her assistance in preparing the scoping of EIA and for the constructive suggestions made by the reviewers to improve the paper.

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