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Evaluation of Environmental Sustainability of Landfill Sites using Rapid Impact Assessment Matrix Method

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Abstract*— *The selection of a suitable disposal option that is ecologically viable, socially acceptable, and economically feasible is the crux of sustainable solid waste management. This paper explores the applicability of Rapid Impact Assessment Matrix for evaluation of options for disposal of municipal solid waste by taking a typical case study of Vijayawada city. Landfill at Nunna and Landfill at Konduru are the two disposal options available for consideration. Environmental sustainability is assessed through an environmental impact assessment of these two proposed projects. This work uses the RIAM tool, which considers all the physical/chemical, biological/ecological, social/cultural, and economical/operational aspects of the proposed project for evaluation. The results obtained show that both the options will have a negative impact on the environment. However, the landfill proposed at Konduru will have minimum negative impacts, nearly 10 times less when compared with the landfill at Nunna. The rapid impact assessment matrix tool found to be useful in quick, rational and cost effective evaluation of options for disposal of municipal solid waste which will be helpful for decision making.

Index Terms*— *Environmental Impact Assessment, Land filling, Municipal Solid Waste, RIAM, Sustainability.

I. INTRODUCTION

The appropriate management of municipal solid waste continues to be a major problem throughout the world. Municipal solid waste (MSW) consists of waste generated by households and commercial activities related to day-to-day human activities. Indiscriminate open dumping and the burning of solid wastes lead to serious environmental issues, such as land pollution, surface water pollution, groundwater pollution, and air pollution. Aesthetic, land use, health, pollution, and economic considerations have made proper solid waste management an ongoing concern for municipal, corporate, and individual functions that must be taken seriously by all.

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The safe and reliable long-term disposal of solid waste is an important component of integrated waste management [1]. Civic bodies have the responsibility of handling solid waste in accordance with the rules outlined by the national policy and legislation for the management of MSW [2].To be responsive to public attitudes, the disciplines that must be considered in integrated solid waste management include the administrative, financial, legal, architectural, planning, environmental, and engineering functions. For a successful integrated solid waste management plan, all these disciplines must necessarily communicate and interact with each other in a positive interdisciplinary relationship [3].

The various solid waste management practices include the processing and recovery of useful material, composting of garbage, biomethanation, waste combustion for energy production, incineration, and landfilling. Based on the biodegradability of solid wastes, options like composting and biomethanation have been adopted [4]. Such waste-to-energy conversion systems are eco-friendly and economical [5, 6]. However, even with the implementation of waste reduction, recycling, and transformation technologies, the disposal of solid waste in landfills remains a significant component of an integrated waste management strategy. The inevitable consequence of the practice of solid waste disposal in landfills is gas and leachate generation primarily due to microbial decomposition, climatic conditions, refuse characteristics, and land filling operations [7]. Typically, little attention has been given to proper siting and engineering to obviate the hazards of the generation of CH_4 and toxic leachates as wastes decompose [8]. The siting of landfills is rapidly becoming the most difficult stage of the process, because few people wish to have landfills in their neighbourhoods. In addition to public acceptability, other considerations for the selection of a site include size, distance of collection, wind, drainage, rainfall pattern, soil type, depth of water table, treatment of leachate, and ultimate use of the landfill site [9]. Sustainability focuses on the relationship between the nature or earth and humans or society [10]. Economic development and environmental degradation are two sides of the same coin. The preservation of natural resources for the future is the key to sustainable development [11]. Disposal of MSW in a scientific and eco-friendly manner that is acceptable to the public and affordable for the local authorities is very essential for sustainable environmental management [12]. However, although solid waste disposal may bring considerable benefits to a city by the way of sanitation, it often results in environmental and social impacts to the wider community. Therefore, balancing the benefits of MSW disposal and environmental protection is crucial for the sustainable management of MSW.

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Critical evaluation of the different disposal options that are available is very essential to minimize the various environmental impacts and to increase the acceptability of the disposal practice. Such evaluation is possible through environmental impact assessment (EIA).

EIA is strongly considered a suitable tool for achieving sustainable development [13-17], due to its ability to evaluate environmental, social, and economic issues. The relationship between sustainability and EIA is well understood and widely used by the scientific community [18-21]. 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 [22].

The disposal of MSW is a burning issue currently being faced by Vijayawada city. Currently MSW is being dumped openly at an already closed landfill near 'Pathapadu' village. The other existing facilities, such as conversion processes and waste-to-energy systems, are in a dilapidated condition and not working due to various reasons. Two landfill sites are proposed at two different areas: 'Nunna' and 'Konduru' in the suburbs of Vijayawada city. The sustainability of these options must be evaluated thoroughly considering ecological, social, economic, and other factors. For this purpose the rapid impact assessment matrix (RIAM) was used. To evaluate the environmental sustainability of the two disposal options available for the effective management of MSW of Vijayawada city, an EIA was carried out with the help of the RIAM software tool. This method was developed as a holistic and reproducible method suitable to compare and identify the major impacts of different options of a project, plan, etc. The RIAM was first described and used by C.M.R. Pastakia [23]. RIAM has been used successfully by many researchers to evaluate the environmental impacts of proposed projects [24-26].The methodology involved mainly data collection and RIAM analysis. In the present work extensive qualitative and quantitative data were collected by visiting the proposed sites, enquiring the local residents, and conducting various surveys. The data were collated and incorporated in the detailed assessment of all possible impacts of each proposed options.

II. STUDY AREA & DATA COLLECTION

The Vijayawada Municipality Corporation (VMC) is located at 16°31'36" N latitude and 80°36'52" E longitudes on the banks of the Krishna River. VMC is spread over an area of 60 sq. km with a population of about 1.04 Millions, as per the 2011 Census report [27]. According to the Central Pollution Control Board, the average waste generated by small towns is 0.1 kg per person per day; for medium towns/cities it is 0.3 to 0.4 kg per person per day, and for large cities it is around 0.5 kg per person per day. With the present population the MSW production is approximately 760 metric tonnes per day. To take care of the future generation of MSW, new proposals have been made, which include two landfilling sites. A landfill is proposed at a village called Nunna which is situated in the agricultural area surrounded by forest. The other site for landfill is proposed at abandoned quarry sites of the village 'Konduru'. A detailed field visit and reconnaissance survey has been conducted to collect all relevant data for giving inputs into the RIAM software tool.

III. CASE STUDIES

For the disposal of MSW of Vijayawada city, two landfill sites were proposed. The description of the landfill sites obtained after rigorous survey and field visits is as follows:

LANDFILL AT NUNNA

Nunna village is situated in the Vijayawada suburban area at 16°37'39.35" N latitude and 80°40'10.49" E longitudes. It is located 15 km from Vijayawada city. Nunna village has residential establishments surrounded by hills, agricultural fields, and forest. The VMC has planned for 100 acres of area for a landfill near Nunna village. This area consists mostly of greenery, with a wide variety of flora and fauna. The groundwater table is at a considerable depth. The construction of a landfill will require a lot of earth work, as the area is hilly. There is no transportation facility to this area. Hence, road construction is essential to implement the landfill project. There are some educational organizations existing in the nearby area. From the field survey a strong opposition from the residents of the area against the construction of a landfill was observed.

Landfill at Konduru

Konduru is a village 35 km from Vijayawada city, at 16°41'23.47" N latitude and 80°34'11.81" E longitudes. It is a hilly area, has less vegetation, and consists mostly of abandoned quarry pits. The proposed site has no agricultural fields or forest area, and it is far away from the residential area. The groundwater table is situated at deep. Arrangements are required for storm water drainage. The soil required for clay lining must be brought from other places. Roads are already laid for quarrying purposes; hence, transportation to the site is easy. As per the survey results, there is no significant resistance from the public to the proposed landfilling in this area. The study area showing the locations of the proposed landfill sites are shown in the Figure 1.

IV. METHODOLOGY

The RIAM method was adopted in this work for evaluation of environmental sustainability through EIA. To structure the impact assessment of the proposed solid waste disposal practice the study focused on four primary fields of concern: physical/ chemical, biological /ecological, sociological /cultural, and economical /operational. The system is based on scoring impact component issues against pre-defined criteria and transporting scores into arranges that describe the degree of positive or negative impacts.

Through the RIAM tool it was possible to quantify the abstract and intangible effects on a defined scale and the cumulative impacts can be compared in a rational manner. The software tool can be freely downloaded from.

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Fig.1: a) Location of the study area b) Proposed area at Konduru c) Proposed area at Nunna

The criteria for giving scores for various components are as follows: A measure of the importance of the relevant condition (A1) is evaluated according to the space boarders or interest of the man that will be affected. The scale is defined in the following way: 0 - Irrelevant/no importance; 1 - Important just to the local condition; 2 - Important to the areas immediately out of the local condition; 3 - Important to the regional/national interest; 4 - Important to the national/international interest. The magnitude (A2) is defined as the measure of the scale of benefit/damage of an impact or condition.

The scale is defined in the following way: +3 - Major positive benefit; +2 - Significant improvement in the status quo ; +1 - Improvement in the status quo ; 0 - No change/status quo; -1 - Negative change to the status quo ; -2 - Significant negative effect or change -3 - Major negative effect or change.

Permanence (B1):1-No change/ not applicable; 2-Temporary; 3-Permanent; Reversibility (B2):1-No change/ not applicable; 2- Reversible; 3- Irreversible; Cumulative (B3): 1- No change/ not applicable; 2-Non-cumulative; 3-Cumulative.

The final assessment score ES is calculated as follows:

$$A1 \times A2 = AT, \quad (1)$$

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

$$ES = AT \times BT, \quad (3)$$

where (A1) and (A2) are the individual criteria scores for group (A), (B1) to (B3) are the individual criteria scores for group (B), AT is the result of multiplication of all (A) scores, BT is the result of summation of all (B) scores, and ES is the assessment score for the condition.

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It is a process of quantifying the qualitative and abstract impacts as per the weights attached to them. Table.1gives the ES score classification range bands.

V. RESULTS AND DISCUSSION

Each disposal option is evaluated by feeding the RIAM tool with the relevant semi-quantitative information regarding the components as per the procedure mentioned above. For example, a component from physical and chemical segment like 'Land use' has been assigned with the appropriate numerical values as described below. Since the 'Land use' is relevant to the areas immediately out of the local condition a value of 2 is given for condition A1. Because the landfill will have a significant negative impact on 'Land use' the magnitude A2 is given a value of -2. The input value for B1 is given as 3 since the effect are permanent and the input value for B2 is given as 3 since it is irreversible. The negative effect on 'Land use' is cumulative with land filling activity hence the input value for B3 is given as 2. Like this all the components are assigned numerical values depending on the relevance conditions, magnitude, permanence reversibility and cumulative effect. The RIAM tool calculates the ES scores and fits all the components in appropriate range bands.

Table. 1. Range bands used for RIAM

Environmental Score (ES)	*Range Bands*	*Range Value*	*Description of range band*
108 to 72	E	5	Major positive change/impact
71 to 36	D	4	Significant positive change/impact
35 to 19	C	3	Moderate positive change/impact
10 to 18	B	2	Positive change/impact
1 to 9	A	1	Slight positive change/impact
0	N	0	No change/status quo/ not applicable
-1 to -9	-A	-1	Slight negative change/impact
-10 to -18	-B	-2	Negative change/impact
-19 to -35	-C	-3	Moderate negative change/impact
-36 to -71	-D	-4	Significant negative change/impact
-72 to -108	-E	-5	Major negative change/impact

Table 2.a. Input values and RIAM scores for Physical/Chemical components

Physical/Chemical (PC)		*Land fill at Nunna*						*Land fill at Konduru*					
Components		A1	A2	B1	B2	B3	ES	A1	A2	B1	B2	B3	ES
PC1	Land use	2	-2	3	3	3	-36	1	2	3	2	2	14
PC2	Dust and debris	1	-2	2	2	2	-12	1	-1	2	2	2	-6
PC3	Odour	2	-3	2	2	2	-36	1	-1	2	2	2	-6
PC4	Surface water quality	3	-3	2	2	3	-63	1	-1	2	2	2	-6
PC5	Groundwater quality	2	-3	3	3	3	-54	1	-2	3	3	3	-18
PC6	Ambient air quality	1	-2	2	2	2	-12	1	-1	2	2	2	-6
PC7	Leachate drainage	1	-2	2	3	2	-14	1	-1	2	2	2	-6
PC8	Storm water drainage	1	-1	2	2	2	-6	1	1	3	2	2	7
PC9	Topography	3	-1	3	3	2	-24	1	1	3	3	2	8
PC10	Land slides	1	-2	2	3	2	-14	1	1	2	3	2	7
PC11	Soil erosion	1	-1	3	3	3	-9	1	1	2	2	2	6
PC12	Ambient noise level	1	-1	2	2	1	-5	1	0	2	2	1	0

Table 2.b. Input values and RIAM scores for Biological /Ecological components

Biological /Ecological (BE)		*Land fill at Nunna*						*Land fill at Konduru*					
Components		A1	A2	B1	B2	B3	ES	A1	A2	B1	B2	B3	ES
BE1	Deforestation and de-vegetation	3	-2	3	3	2	-48	1	0	3	3	2	0
BE2	Natural habitats	3	-1	3	3	2	-24	1	0	3	3	2	0
BE3	Biodiversity	3	-2	3	3	2	-48	1	-1	3	3	2	-8
BE4	Flora and fauna	3	-2	3	3	2	-48	1	-1	3	3	2	-8
BE5	Wildlife and birds	3	-2	3	3	2	-48	1	0	3	3	2	0

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BE6	Endemic species	3	-1	3	3	2	-24	1	0	3	3	2	0
BE7	Ecological balance	3	-2	3	3	2	-48	1	-1	2	2	2	-6
BE8	Rodent and fly growth	1	-2	2	2	2	-12	1	-1	2	2	2	-6
BE9	Ground water pollution	2	-2	2	2	2	-24	1	-1	2	2	2	-6
BE10	Surface water pollution	2	-2	2	2	2	-24	1	-1	2	2	2	-6
BE11	Insects and vectors	1	-2	2	2	2	-12	1	-1	2	2	2	-6
BE12	Climate change due to methane	4	-3	3	3	3	-108	4	-3	3	3	3	-108

Table 2.c. Input values and RIAM scores for Sociological Cultural components

Sociological Cultural (SC)		***Land fill at Nunna***						***Land fill at Konduru***					
Components		A1	A2	B1	B2	B3	ES	A1	A2	B1	B2	B3	ES
SC1	Loss of livelihood	1	-2	3	3	2	-16	1	0	2	2	2	0
SC2	Loss of agricultural land	2	-3	3	3	2	-48	1	0	2	2	2	0
SC3	Loss of residential area	1	-2	3	3	2	-16	1	0	2	2	2	0
SC4	Loss of cultural heritage	1	-1	3	3	2	-8	1	0	2	2	2	0
SC5	Employment	1	1	2	2	2	6	1	1	2	2	2	6
SC6	Health and hygiene	2	-2	2	2	2	-24	1	-1	2	2	1	-5
SC7	Sanitation	1	-2	2	2	2	-12	1	-1	2	2	1	-5
SC8	Transportation network	2	2	3	3	2	32	1	1	2	3	1	6
SC9	Electricity facilities	1	1	3	2	2	7	1	1	3	3	2	8
SC10	Community development	1	1	3	3	2	8	1	1	2	3	2	7
SC11	Traffic intensity	1	-1	2	2	2	-6	1	-1	2	2	2	-6
SC12	Landscape and Scenic beauty	2	-2	3	3	2	-32	1	-1	3	3	2	-8

Table 2.d. Input values and RIAM scores for Economical /Operational components

Economical /Operational(EO)		***Land fill at Nunna***						***Land fill at Konduru***					
Components		A1	A2	B1	B2	B3	ES	A1	A2	B1	B2	B3	ES
EO1	Land cost	1	-2	3	3	2	-16	1	-1	3	3	2	-8
EO2	Loss of nearby land value	2	-2	3	3	2	-32	1	0	3	3	2	0
EO3	Loss of Mineral and other resources	1	-2	3	3	2	-16	1	-1	3	3	2	-8
EO4	Rehabilitation and resettlement costs	1	-2	3	3	2	-16	1	-1	3	3	2	-8
EO5	Urban development	2	2	2	2	2	24	2	1	3	3	3	18
EO6	Biogas production	1	1	2	2	1	5	1	1	2	2	2	6
EO7	Transportation cost	1	-2	2	2	2	-12	1	-1	2	3	2	-7
EO8	Earthmoving equipment costs	1	-1	2	2	2	-6	1	-2	3	3	2	-16
EO9	Construction cost	1	-1	2	2	2	-6	1	-1	2	3	2	-7
EO10	Site maintenance cost	1	-1	2	2	2	-6	1	-1	2	3	2	-7
EO11	Equipment for Leachate treatment	1	-1	2	2	2	-6	1	-1	2	3	2	-7
EO12	Fuel costs	1	-2	2	2	2	-12	1	-2	2	3	2	-14

Table 3. Summary of scores for Land fill at Nunna

Range	**-108 to -72**	**-71 to -36**	**-35 to -19**	**-18 to -10**	**-9 to -1**	**0**	**1 to 9**	**10 to 18**	**19 to 35**	**36 to 71**	**72 to 108**
Class	-E	-D	-C	-B	-A	N	A	B	C	D	E
PC	0	4	1	4	3	0	0	0	0	0	0
BE	1	5	4	2	0	0	0	0	0	0	0
SC	0	1	2	3	2	0	3	0	1	0	0
EO	0	0	1	5	4	0	1	0	1	0	0
Total	1	10	8	14	9	0	4	0	2	0	0

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Table 4. Summary of scores for Land fill at Konduru

Range	-108 to -72	-71 to -36	-35 to -19	-18 to -10	-9 to -1	0	1 to 9	10 to 18	19 to 35	36 to 71	72 to 108
Class	-E	-D	-C	-B	-A	N	A	B	C	D	E
PC	0	0	0	1	5	1	4	1	0	0	0
BE	1	0	0	0	7	4	0	0	0	0	0
SC	0	0	0	0	4	4	4	0	0	0	0
EO	0	0	0	2	7	1	1	1	0	0	0
Total	1	0	0	3	23	10	9	2	0	0	0

Option 1: Landfill at Nunna

There is a considerable negative impact on the physico-chemical environment of Nunna village due to the proposed landfill. This is mainly due to the alteration of land use, topography, ambient air quality, surface water and groundwater quality, and nuisance due to dust and debris, leachate, odour, and noise. The proposed site for a landfill at Nunna village consists of forest area and agricultural fields. Hence, all components selected for study under the biological and ecological segment got negative scores. Deforestation, loss of natural habitats and biodiversity, growth of rodents, flies, and disease-causing insects, and soil pollution will completely destroy the ecological balance of the area. The production of methane, if not properly collected and managed, can pose a severe threat to the global environment by contributing to global warming. There is a significant negative impact on the sociological and cultural environment of the area due to the proposed landfill. This is mainly due to the loss of agricultural land, residential area, health and hygiene, and sanitation. The development of roads, electrical facilities, and employment and community development are the positive effects of the project. Other than the urban development of Vijayawada city, the proposed project will have a negative impact on the economic and operational segment in the Nunna area. This may be due to the loss of land value and agricultural potential, and the huge costs of fuel, earthmoving equipment, leachate treatment, and rehabilitation and resettlement.

Option 2: Landfill at Konduru

The proposed site in Konduru village consists mainly of barren land and abandoned quarry pits in hilly terrain. Hence, the better utilization of an abandoned site is a positive benefit in the physico-chemical environment of Konduru village. Other minor negative impacts in this segment include air and water quality, noise, soil erosion, and landslides.

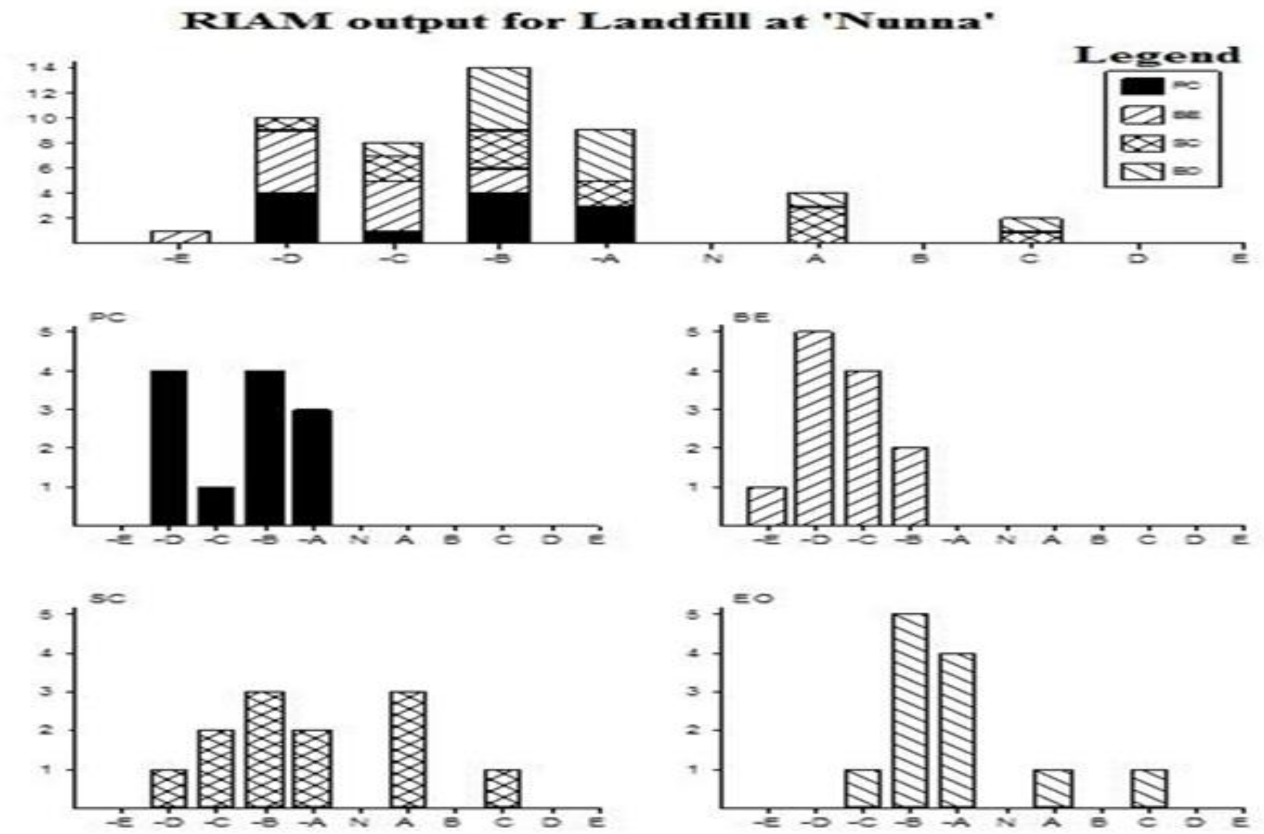

Fig.2. RIAM Graphical output for Landfill at 'Nunna'

Except for climate change due to methane there are no significant negative impacts in the biological and ecological environment of the area. The main reason is that the site consists of abandoned stone quarry pits with no agriculture or forest land. The proposed project will have minor negative impacts in the sociological and cultural segment in terms of loss of health and hygiene, sanitation, scenic beauty, and increased traffic. As the landfill site is situated 35 km from the centre of Vijayawada city, transportation costs will be high. This will become a negative impact under this option. The input values fed in to the RIAM tool and the corresponding Environmental score are given in the Tables 2.a to 2d. The summary of RIAM scores for Land fill at Nunna and Land fill at Konduru are given in the Table 3 and 4. Graphical outputs of the RIAM tool are shown in Figs. 2 and 3 for the options at Nunna and Konduru respectively. The graphical output gives us a rapid glance at the overall impact of the proposed option on the environment. N stands for neutral and +ve and –ve alphabets on x-axis shows positive and negative impact of the component.

From the results of the RIAM analysis, it was observed that the first options obtained more negative scoring and has serious negative impacts on the environment. Total positive and negative scores of the option 1 and 2 are given in the Table 5 below for comparison.

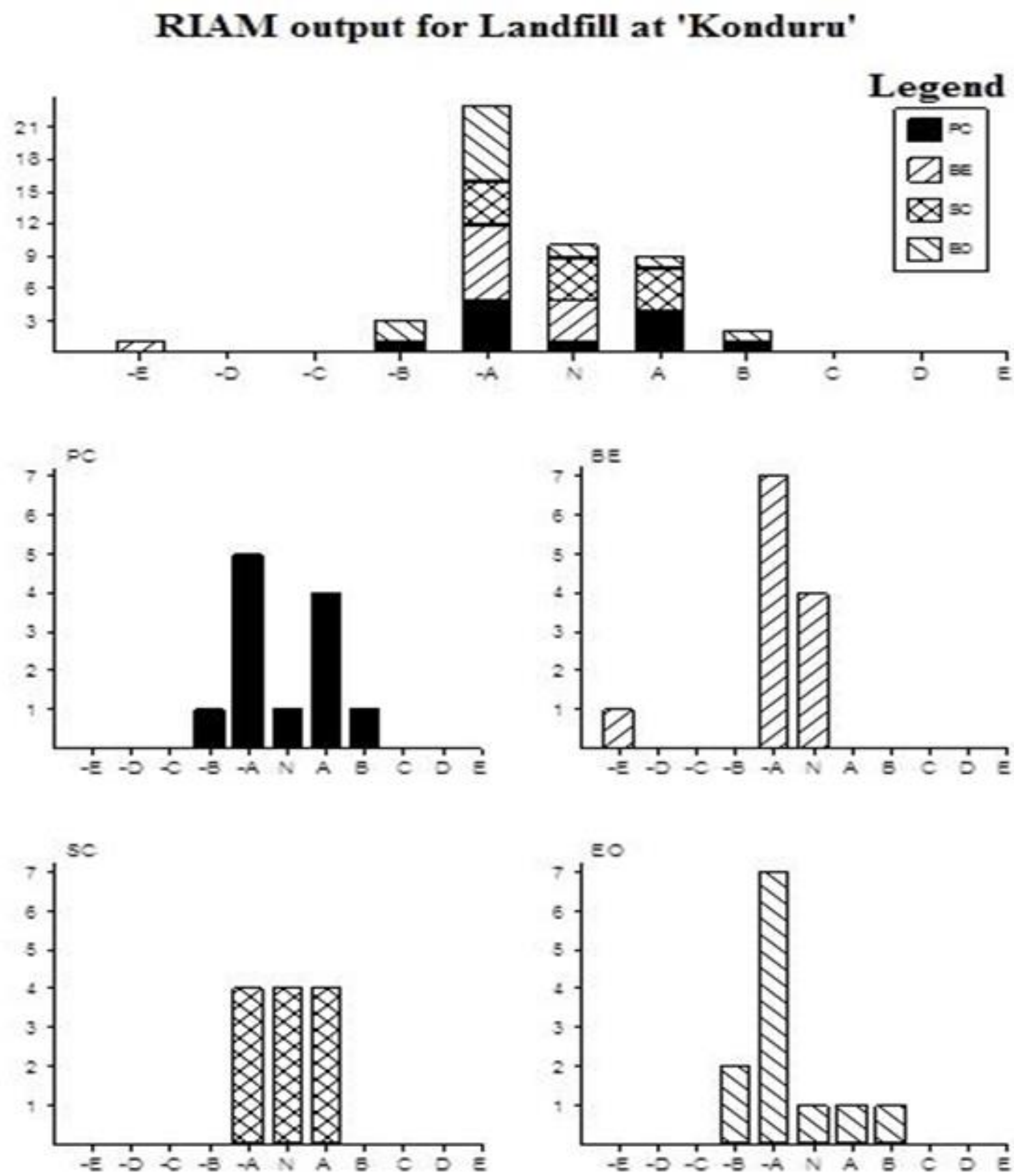

Fig.3. RIAM graphical output for Landfill at 'Konduru'

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Table 5. Total scores for the two options

Options	*Score for Positive effect*	*Score for Negative effect*	*Score for No effect*	*Total Score*
Option-1: Landfill at Nunna	10	-106	0	-96
Option-2: Landfill at Konduru	13	-34	10	-11

Both the options are going to cause negative impacts on the environmental sustainability. The negative impacts caused by option 1 are more than option 2. The positive effects of the two options are almost same. However, to handle the issue of disposal of the MSW generated in Vijayawada, there is no other way except to select one option from the two available. From the option summary it is obvious that a landfill at Konduru has less negative effects. Hence, option 2, a landfill at Konduru, can be selected as the option for the disposal of the MSW of Vijayawada city. However a proper environmental management plan is to be adopted to minimize the negative impacts mentioned above.

VI. CONCLUSION

Disposal of MSW in a scientific and eco-friendly manner that is acceptable to the public and affordable for the local authorities is very essential for sustainable environmental management. Sustainability of disposal options can be better assessed through EIA. RIAM is a software tool which can be effectively used for EIA in a very rapid and cost effective manner once the options are available beforehand. Through this paper the applicability of RIAM was demonstrated. The disposal of around 760 tonnes of MSW produced daily has become a herculean task to the Vijayawada Municipal Corporation. Landfills at Nunna and Konduru are the two proposed disposal options. The RIAM results shows that Landfill at Nunna has got total score as -96 and landfill at Konduru has got total score as -11. Negative sign indicate the negative impact on environment. Both the options will have a negative impact on the environment however, it can be concluded that a landfill at Konduru is suggestible for the disposal of the MSW of VMC with further detailed study and proper environmental management plan. This paper evaluated the environmental sustainability of these options using RIAM tool which is rapid, rational and cost effective and helps in decision making.

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