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Industrial Waste Management with Application of RIAM Environmental Assessment: A Case Study on Toos Industrial State, Mashhad

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Abstract: Systematic industrial waste management is one of an important issue due to high environmental risks caused by improper waste disposal. Hence, present research was conducted to investigate environmental aspects of optimal disposal and management methods of industrial waste of Toos industrial estate in Mashhad. In this work, one of the environmental impact assessment methods called Rapid Impact Assessment Matrix (RIAM) was applied. Thus, various disposal options such as open dumping, sanitary landfill, gasification and incineration from the viewpoint of the physical, chemical, biological, ecological, cultural and social, economical and environmental aspects were evaluated. All of these aspects were compared due to selection of disposal methods through application of RIAM technique. The obtained results showed that sanitary landfill led to more beneficial effects than the other four mentioned options. Therefore, the best method of choice in compare to other options for waste management in the industrial estate of Toos, Mashhad was selected.

Key words: Waste management · Rapid matrix · Environmental impact assessment · Toos industrial estate · Industrial waste

INTRODUCTION

One of the major environmental problems encountered in the country's big cities is Municipal, industrial, healthcare and hazardous solid wastes management. Industrial and hazardous waste management, among all of these different kinds of wastes is great important issue due to the lack of proper planning and management which leads to extensive pollution of surface and ground water, soil and atmosphere of surrounding environment. Considering the importance of this issue and the overall approach to archive a proper comprehensive waste management, industrial waste management is one of the main axes of the comprehensive waste management that requires special attention and consequently systems for management and control of any pollution sources.

Intensity of environmental pollution caused by municipal and industrial wastes is in a manner that has attracted the scientific resources and administrative authorities' attention all over the world. In fact, implementation of recycling or proper disposal of any waste materials is absolutely necessary [1]. Increase in amount of solid waste due to industrial development and rapid growth in population and consequently increase in amount consumed materials, has caused serious crisis in human societies [2, 3]. Improper Transfer and disposal of industrial waste that contain some hazardous materials, create serious problems for human and the safe environment. Thus, applying effective methods in control and management of industrial waste for hygiene industrial waste management initially started in the United States of America by adoption of resource conservation and recovery act in 1976. Guideline No. 21 as a global and systematic plan for achieving sustainable development; has devoted its chapter twenty to solid and hazardous waste management and also has recommended to prevent further growth in generation of waste and waste minimization through the codification of implementation plans. So far, many studies have been conducted in the field of waste management. Morrissey and Browne [4] have proposed that a sustainable waste management system should be effective and practical in environmental and economic terms, as well as being socially acceptable. In order to provide optimum management of solid offered a set of attributes containing technical, economic, environmental and social aspects [5].

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There are some researches were conducted in the field of industrial solid wastes in Iran [6]. Industrial waste of Tehran and the relationship between weight and volume of produced waste with the number of staff working in factories were investigated [7]. In another study, qualitative and quantitative characteristics of waste of BouAli industrial estate in Hamadan was evaluated [8]. It was defined that if there is enough information about household and industrial waste components and also useful information about the capita production of different kinds of waste in this estate; then one can establish a management system for industrial waste. Deficiency of mentioned previous researches is that a comprehensive management system that can be extended to other parts of the country was not defined; instead most effort was carried out to propose a single solution to achieve a final disposal of all kind of industrial waste.

As a result of studies it has been proven that an integrated management system for organizing industrial waste is required. However, none of these previous studies has discussed on strategies to achieve this goal. Therefore, in this study, industrial waste generation in Toos industry estate has been studied to select the best scenario in terms of technical and environmental waste management. Environment and resource management is particularly important [9, 10]. Furthermore, there are many incentives for different industries and institutions around the world to apply waste management as mentioned below.

Economic Incentives: More benefit, obtaining production license or export licenses, reduction in environmental fines and incredible increase in waste treatment and disposal costs (especially in developed countries).

Legal Reasons: To observe the environmental laws, in other word to compliance with environmental regulations enacted by local, national and international authorities.

Public Protests: Public demands, increased sensitivity, awareness and experience of the human, about hazardous waste.

Moral Requirements: Managers and experts on human health and the environment need to comply with the ethical requirements.

Considering extent of the estate and resulting large amounts of waste production, waste management is not in good condition. Hence, an environmental impact assessment technique namely RIAM is used to evaluate the different scenarios for the waste management of the estate.

The RIAM method is a useful and productive approach in evaluation of environmental and human impacts (positive and negative) with respect to current and potential operations. It was presented by Pastakia [11, 12]. It has developed a good reputation as a reliable method, as well as having the transparency often lacking in some other methods. This is due to the use of a semi-quantitative approach which requires justification of scores derived by the assessor(s). Moreover, there are many articles which use RIAM technique to evaluate the impacts of projects or natural systems including; concerning municipal waste disposal options for a site in Varanasi, India [13]; the environmental impacts arising from the exploration, drilling and operation of the Sabalan geothermal power plant in Iran was investigated [14]; and also RIAM was used to evaluate the impact of humans upon coastal morphology in Kuwait [15]. Furthermore, the usability of RIAM approach has been evaluated by Kuitunen *et al*. and Ijäs *et al*. [16, 17]. Kuitunen and his coworkers [16] have explored whether the RIAM could be used to compare results obtained in an EIA and a SEA (Strategic Environmental Assessment). Kuitunen *et al*. [16] have determined that it was possible to evaluate and compare different projects, plans and programs using the RIAM as a method. Ijäs *et al*. [17] have evaluated the use of the method with respect to impact significance

As a definition, assessment is an important technique to ensure that potential impacts of development projects on environment are fully identified and considered in calculations. In other words, the word assessment refers to a procedure for determining, prediction and interpretation of environmental impacts of a project on environment, public health and ecosystems which human life depends on.

In summary, the general concepts of assessment can be summarized as follow:

- It's a study on effects of a proposed activity on environment.
- It provides comparison and incorporation of different reasonable options.
- It determines a desirable goal.
- It sought to determine the best option. Selected optimum Options is the one with reasonable costs and benefits (Costs and benefits of the selected desirable optimum options are reasonable).

- It's based on prediction of qualitative changes in the environment made by a proposed action.
- It evaluates environmental impacts from the point view of economic costs and benefit aspects.
- It's a decision making tool.

Any project has several effects on surrounding environment such as affecting physical environment, biological, economical social and cultural environment. Moreover, environmental effects of a project on physical environment include effects on climate and air quality, effects on water, soil and the effect on the sound pollution. Sometimes, it's difficult to identify and predict the effects on climate, especially in some specific project. Another environmental impact of a project is affecting biological environment, including effects on vegetation and animals. The Effects on vegetation are divided into following categories namely; direct and indirect impacts. Other part of the surrounding environment that can be affected by a project is socio-economic environment. Socio-economic environment may change in construction and utilization phase.

The present research is conducted to investigate the environmental aspects of various methods of industrial waste management and disposal in Toos industrial estate by application of RIAM technique to assess the waste management in terms of physical, chemical, biological, ecological, cultural, social, economic and environmental aspects.

MATERIALS AND METHODS

Case Study: Toos industrial estate is located beside science and technology park, Samen complex and food industry estate on 18 kilometer Asian highway in the northwest of Mashhad city in northeast of Iran, with a total area of 425 hectares. It has 768 factories where more than 35 thousand people live in nearby.

The maximum weight of waste generated per day is 180 tons. Average moisture content of waste is about 6 %, which represents the majority of dry waste production. Actually wastes consist of 66.6% of solid and 6.6% of liquid portion. About 43.23 % of the waste is flammable and 56.6% is non-flammable materials. Waste segregation is performed in 77 cases and only in 30% of cases, waste processing is preformed. Temporary storage tools consist of 53.33% plastic containers and 33.53% plastic bags. As a temporary storage, containers are used in 20% of cases; the remaining 80% consist of 40% of roofed places and 40% of non-enclosed areas. Transportions vehicles used to disposal site in 36.66 and 53.33% of cases are truck and pickups, respectively. It seems that in this estate, transportation of waste to disposal sites is not performed in a proper systematic manner.

Investigating quality of the temporary storage from the viewpoint of sanitary (considering different factors such as standard storage containers, odor production, existence of insects and rodents, etc.) has demonstrated 56.66 % of medium and 20 of poor state. About 73.33 % of the recyclable waste is buried in landfill and 6.66 % is incinerated.

Temporary storage of waste takes an average duration of 3 to 6 days. Performed monitoring is negligible and is done with a relatively high interval. Moreover, wastes enter into the production process in an improper manner (such as improper reuse of waste in manufacturing process, reducing waste at point source of production process, collecting solid waste by hand and by untrained individuals) that might result in health hazards.

General Approach: In order to evaluate environmental impacts and to achieve optimum waste management of Toos industrial estate RIAM method was used [11, 12].

In four criteria categories namely; 1) Economic/operational, 2) Physical/chemical, 3) Sociological/cultural and 4) Biological, all the related criteria due to the local conditions were investigated. Moreover, these criteria were scored as the following method. However, the scorings are presented in Table 1.

In the next step, the effects of the chosen criteria were scored using defined criteria. Due to the RIAM scoring system two groups of scores are used including "a" and "b".

In this scoring system, scores corresponding to first group are multiplied by each other. Thus, these criteria will weigh more in scoring and as the scores of the second group are summed together they will weight lower but they are considered in scoring yet. Both scores are multiplied together to determine the final environmental assessment score or "ES". The scoring formula is as follow:

$$(a_1)*(a_2)=aT \quad (1)$$

$$(b_1)*(b_2)=bT \quad (2)$$

$$(aT)*(bT) = ES \quad (3)$$

Table 1: Indexes of RIAM environmental assessment

Economic / operational components	Physical/chemical components
Cost of building a new landfill	Leachate generated in the current landfill
cost of expansion of the current landfill	Collecting leachate using drainage system
Leachate collection costs	Discharge and re-use of Leachate
Leachate treatment costs	Discharging treated leachate into municipal wastewater
Cost of monitoring, sampling and analysis of waste of the estate waste	Current situation of recycling and treatment facilities of estate
New Land occupancy costs for facilities	Leachate seepage to groundwater
construction and operation cost of incinerators	Odor control and maintenance
Waste Recycling costs	Greenhouse gases and other gases emission
costs of the estate waste (gathering)collection	Gases emissions control and Recycling methods
Resulting Income from products or energy produced by recycling or Incineration of waste	industrial waste incineration ashes Processing and treatment
	Compatibility of the waste with disposal method
	Separation of the various components of industrial waste before landfilling
Sociological/cultural components	Biological components
Residential areas close to landfill	Impacts on groundwater by Leachate seepage
Public problems caused by dust	Impacts on soil
Public problems caused by noise	Impacts on ecosystem
public comments on the re-use of recycled materials and employment in the area	effects on waste decomposition of wastes
Odor problems caused by industrial waste	soil erosion, Creation of excess runoff
	open landfill risks

Table 2: RIAM method Assessment criteria [10, 11]

Criteria	Scale	Description
a_1: importance of condition	4	Important to national/international interest
	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
a_2: magnitude of change/ effect	3	Major positive benefit
	2	Significant improvement in status quo
	1	Improvement in status quo
	0	No change/status quo
	-1	Negative change in status quo
	-2	Significant negative disbenefit or change
	-3	Major disbenefit or change
b_1: permanence	1	No change/not applicable
	2	Temporary
	3	Permanent
b_2: reversibility	1	No change/not applicable
	2	Reversible
	3	Irreversible
b_3: cumulative	1	No change/not applicable
	2	Non-cumulative/single
	3	Cumulative/synergistic

Table 3: Conversion of environmental scores to range bands [10, 11]

Description	Range bands	Environmental score (ES)
Major positive change/impacts	+E	72+ to 108+
Significant positive change/impacts	+D	36+ to 71+
Moderately positive change/impacts	+C	19+ to 35 +
Positive change/impacts	+B	10+ to 18+
Slightly positive change/impacts	+A	1+ to 9+
No change/status quo/not applicable	N	zero
Slightly negative change/impacts	-A	-1 to -9
Negative change/impacts	-B	-10 to -18
Moderately negative change/impacts	-C	-19 to -35
Significant negative change/impacts	-D	-36 to -71
Major negative change/impacts	-E	-72 to -108

In first group a_1 and a_2 indicate the importance and magnitude criterion of the impact respectively. In second Group criteria b_1, b_2, b_3, respectively; that indicate the permanent reversibility and cumulative criterion (Table 2).

Obviously, it should be initially determined if the effect is positive or negative and then the scoring would be done. In order to analyze results of the scoring in this method, resulting environmental scores (ES) should be investigated in Table 3 range bands. Therefore, range bands of positive and negative impacts for each component of the environment should initially be determined. Finally, the option that has the least negative impact is selected.

In order to provide Waste Management using RIAM in this estate the following four different scenarios were considered:

- Open dumping,
- Sanitary landfill,
- Gasification,
- Incineration.

RESULTS AND DISCUSSION

For instance, rapid matrices for the second scenario (sanitary landfilling) are illustrated in Table 4, whereas other scenarios' matrices due to lack of space are not presented here. However, the summary of rapid matrix scoring for all the scenarios is presented in Table 5.

First Scenario; Open Landfill: The results for the first scenario do not contain any positive impact and this is due to the direct effect of waste decomposition on soil as

Table 4: Rapid matrix for second scenario, sanitary landfill

Components	a_1	a_2	b_1	b_2	b_3	aT	bT	ES	RB
Physical/chemical component	Physical/chemical components								
Current waste in estate	1	-1	2	2	3	-1	7	-7	-A
Leachate generated in the current landfill	1	-1	2	2	3	-1	7	-7	-A
Collecting leachate using drainage system	2	1	2	3	2	2	7	14	B
Discharge and re-use of Leachate	2	1	2	3	2	2	7	14	B
Discharging treated leachate into municipal wastewater	3	2	2	3	3	6	8	48	D
Current situation of recycling and treatment facilities of estate	2	1	2	3	1	2	6	12	B
Leachate seepage to groundwater	3	-1	3	3	3	-3	9	-27	-C
control and maintenance of Odor	2	1	2	2	3	2	7	14	B
Greenhouse gases and other gases emission	3	-1	3	3	3	-3	9	-27	-C
Gases emissions control and Recycling methods	3	3	3	3	3	9	9	81	E
industrial waste incineration ashes Processing and treatment	2	2	2	3		4	5	20	C
Biological/ecological components	Biological/ecological components								
Impacts on groundwater by Leachate seepage	3	-1	2	2	3	-3	7	-21	-C
Impacts on soil	3	-1	3	3	3	-3	9	-27	-C
Impacts on ecosystem	2	-1	3	2	3	-2	8	-16	-B
effects on waste decomposition of wastes	2	1	2	2	2	2	6	12	B
soil erosion, Creation of excess runoff	2	-1	2	2	2	-2	6	-12	-B
open landfill risks	2	-1	2	2	2	-2	6	-12	-B
Social/cultural components	Social/cultural components								
Residential areas close to landfill	1	2	2	2	3	2	7	14	B
Public problems caused by dust	1	2	2	2	3	2	7	14	B
Public problems caused by noise	1	1	2	2	3	1	7	7	A
public comments on the re-use of recycled materials	1	1	2	2	2	1	6	6	A
employment in the area	1	2	2	2	3	2	7	14	B
Odor problems caused by industrial waste	2	2	2	2	3	4	7	28	C
Economical/operational components	Economical/operational components								
Cost of building a new landfill	1	1	1	1	1	1	3	3	A
cost of expansion of the current landfill	1	2	2	3	3	2	8	16	B
Leachate collection costs	1	1	1	1	1	1	3	3	A
Leachate treatment costs	1	2	2	3	3	2	8	16	B
Cost of monitoring, sampling and analysis of waste of the estate waste	1	-1	3	2	3	-1	8	-8	-A
New Land occupancy costs for facilities	1	-1	2	2	1	-1	5	-5	-A
construction and operation cost of incinerators	1	1	2	2	2	1	6	6	A
Waste Recycling costs	1	1	2	2	2	1	6	6	A
costs of the estate waste (gathering)collection	1	1	2	2	2	1	6	6	A
Resulting Income from products or energy produced by recycling or Incineration of waste	2	1	2	3	2	2	7	14	B

Table 5: Summary of rapid matrix scoring

First scenario											
Category	(E	-D	-C	-B	-A	N	A	B	C	D	E
PC	0	3	3	1	0	0	4	0	0	0	0
BE	0	4	0	1	1	0	0	0	0	0	0
SC	0	1	1	3	0	0	0	1	0	0	0
EO	0	1	0	3	2	0	1	3	0	0	0
Total	0	9	4	8	3	0	5	4	0	0	0
Second scenario											
PC	0	0	2	0	2	0	0	4	1	1	1
BE	0	0	2	3	0	0	0	1	0	0	0
SC	0	0	0	0	0	0	2	3	1	0	0
EO	0	0	0	0	2	0	4	3	0	0	0
Total	0	0	4	3	4	0	6	11	2	1	1
Third scenario											
PC	2	2	1	2	1	0	1	1	0	1	0
BE	3	3	1	0	0	0	0	0	0	0	0
SC	0	2	1	1	1	0	0	1	0	0	0
EO	0	4	2	1	2	0	1	1	0	0	0
Total	5	11	5	4	3	0	2	3	0	1	0
Fourth scenario											
PC	3	2	1	0	0	0	0	4	0	0	1
BE	0	6	0	0	0	0	0	0	0	0	0
SC	0	3	0	1	0	0	2	0	0	0	0
EO	0	2	1	2	4	0	0	0	1	0	0
Total	0	1	4	2	0	4	0	3	0	2	13

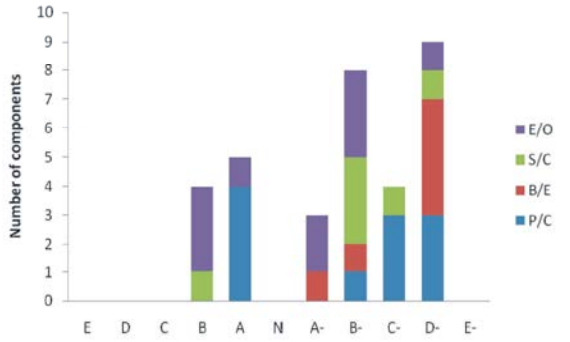

Fig. 1: Representing assessment result of the first scenario by RIAM method
EO indicates economical/operational components, SC indicates social/cultural components
BE indicates biological/ecological components, PC indicates physical/chemical components

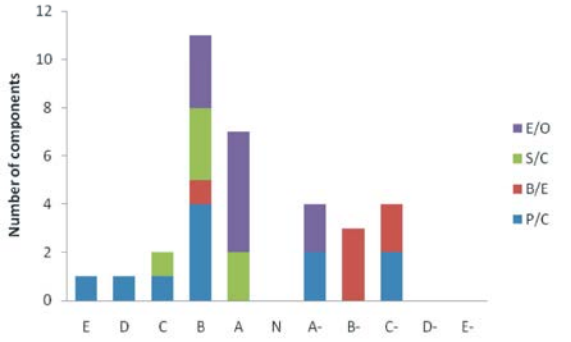

Fig. 2: Representing assessment result of the second scenario by RIAM method

well as the impact on the water due to the direct leaching of existing heavy metals in waste. Moreover, the assessment result of the first scenario is illustrated in Fig. 1.

Second Scenario; Sanitary Landfill: It's is considerably better than first scenario in term of performance and it provides reduction in amount of CH_4 and other organic compounds such as pesticides (Vinyl chloride, benzene and toluene) emission in to atmosphere. The other positive effects can be pointed to as: there is no stench, it reduces the menace caused by birds and rodents and also minimizes the risk of fire due to regular extracting of gasses. This gas can be sold as fuel, which in turn provides costs reduction. Moreover, the assessment result of the second scenario is illustrated in Figure 2.

Third Scenario; Gasification: This scenario results in most negative impacts. It requires regular maintenance and cleaning of the system. It leads to releasing of chemicals that are toxic to vegetation and soil. On the other hand, the gas fuel is easier to transport the solid. The most positive effects of pollution control during the process of gasification are producing no harmful gases. Moreover, the assessment result of the third scenario is illustrated in Figure 3.

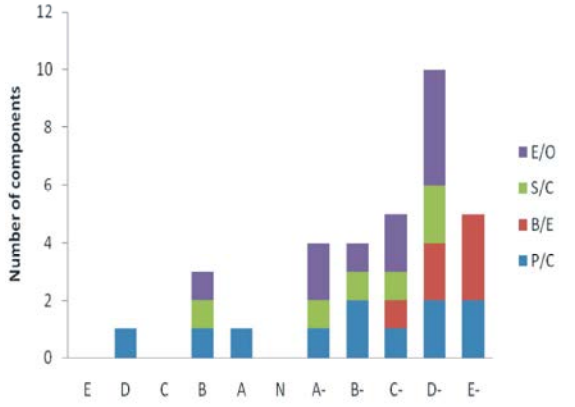

Fig. 3: Representing assessment result of the third scenario by RIAM method

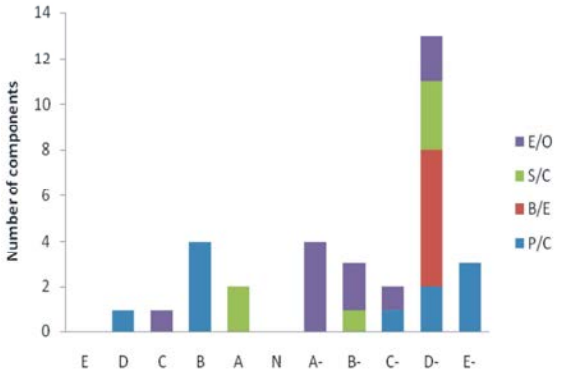

Fig. 4: Representing assessment result of the fourth scenario by RIAM method

Fourth Scenario; Incineration: Its greatest impact is on air pollution. The pollution induced by this scenario is mainly caused due to NO_2, SO_2 and NO_x Particles, which have negative impacts on human health (including physical, chemical, biological, ecological and sociological negative effects). The most important positive effect of incineration is reducing the size of waste, which may reduce the problem of waste accumulation. Moreover, the assessment result of the forth scenario is illustrated in Fig 4.

CONCLUSION

Open dumping is not recommended due to leachate which comprises heavy metals and may contaminate groundwater, stench and microbes that present in the pit and have negative effects on people health in Toos estate and also due to the noise pollution made by vehicle traffic. Moreover, gasification is not economical due to toxic chemicals releases and side costs such as maintenance cost. Incineration is not a beneficial scenario due to air pollution caused by gases, CO_2, SO_2 and NO_x. RIAM analysis results lead to choose sanitary landfilling as the most proper scenario, based on the minimization of the negative environmental impacts, reduces harmful gasses and toxic organic compounds emissions into the air and minimizes leaching problems. In addition, it has no odor problems. Also, it protects environment and human health as well as reducing economic problem by producing gases which can be used in procedure of electricity generation.

Considering The results of the evaluation and comparison of these four scenarios, the second scenario (sanitary landfill) has the least negative impact on the environment. However, this study leads to the following conclusions which are concluded for Toos industrial estate.

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