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Full Length Research Paper

Selection of optimum option for sludge disposal in the Guilan province of Iran using rapid impact assessment matrix (RIAM)

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All wastewater treatment processes produce a large amount of semisolid pollutants, especially wastewater sludge. Discharge of sludge without environmental considerations will have many serious effects on public health and environment. The main objective of this study is the selection of optimum option for sludge disposal in the Guilan province of Iran using rapid impact assessment matrix (RIAM) which is a tool to organise, analyse and present the results of a holistic environmental impact analysis (EIA). The effects of five options of sludge disposal (sludge composting, co-composting, grass land application, sanitary landfill and incineration) on four environmental components (physical-chemical, biological-ecological, social and economical) are evaluated via questionnaires which were was addressed to all environmental experts in water and wastewater companies in Guilan province. It was found that there are different optimum options for each environmental component. Based on overall comparison of the options' effects on all the components, the analysis of matrices has shown that co-composting is the best recommended option for sludge disposal in the existing conditions.

Key words: Sludge disposal, environmental impact assessment (EIA), rapid impact assessment matrix (RAIM), Guilan province, environmental components.

INTRODUCTION

All wastewater treatment processes produce a large amount of semisolid pollutants, especially wastewater sludge. Sludge from wastewater treatment is a concentrated liquid, with characteristics that vary according to the type of plant and method of operation. The solid concentration in sludge varies between 1 to 6% by weight (Turovskiy and Mathai, 2006). The treatment and disposal of sludge are two of the most important and complex subjects in wastewater engineering. Discharge of sludge without proper treatment will have many serious effects on public health and environment. Therefore, sludge should be treated before being discharged into the environment. In selecting the appropriate methods for sludge processing, disposal and reuse, considerations must be given to the relevant standards and regulation (Iran EPA, 2005).

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The Guilan province is located in southern side of the Caspian Sea. In this province, there are various internationally registered natural resources such as wetlands, lakes, rivers, forests, etc. Improper sludge discharge can have adverse effects on these natural resources and public health (Farrokhi et al., 2008). There are three sludge treatment plants in the cities of Rasht and Anzali that at the present produce 40 m3/day of dewatered sludge (GWWC, 2010). Non proper sludge disposal can have adversely affects on these natural resources and public health (Farrokhi et al., 2008). The choice of a sludge disposal system should be based on their environmental effects (Poulsen and Hansen 2003). Different environmental impact assessment (EIA) methods are used for sludge management technologies for example Life Cycle Assessment method used to compare different options for sludge treatment and so as to determine which option is the most environmentally sound (Ngelah and Per, 2008). The main objective of this study is to conduct the selection of optimum option

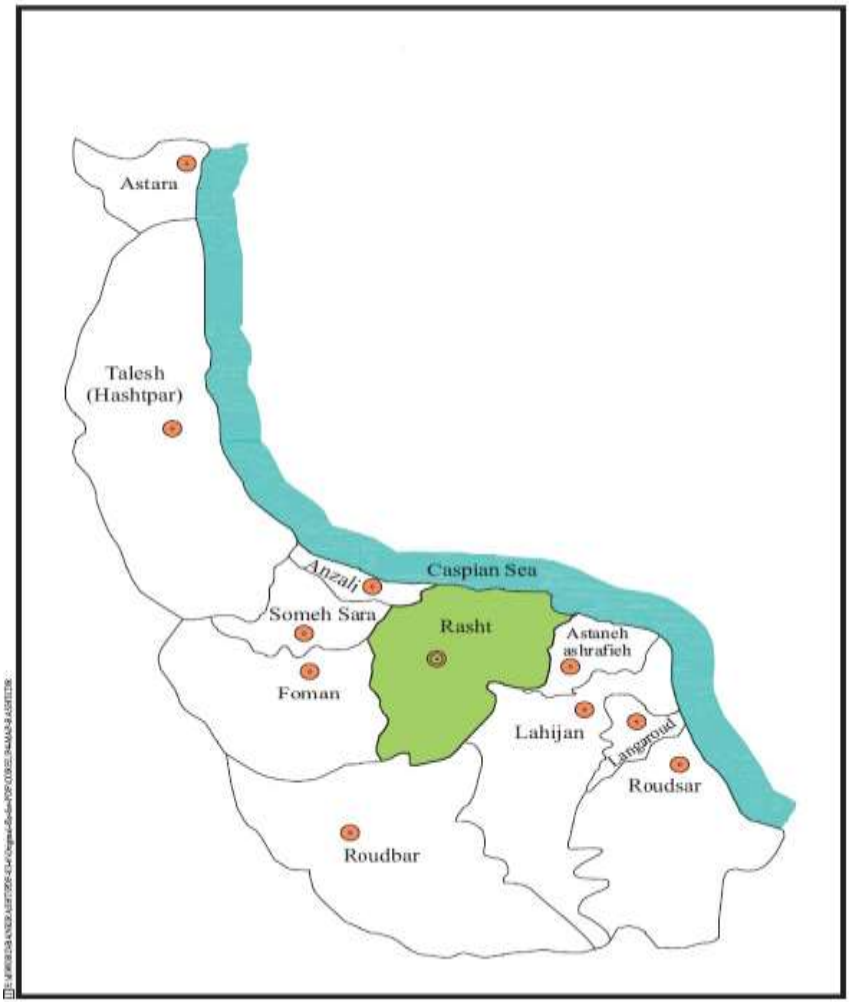

Figure 1. Guilan province and its townships

for sludge disposal in the Guilan province using rapid impact assessment matrix (RIAM), which is a tool to organise, analyse and present the results of a holistic environmental impact analysis (EIA). The simple and structured form of RIAM allows for reanalysis and in depth analysis of selected components in a rapid and accurate manner (Pastakia and Jensen, 1998). RIAM has the capability to make multiple “runs” to compare different options. RIAM is able to compare (on a common basis) judgments made in different sectors as the methods follow a defined set of judgment rules. The scales in RIAM allow both quantitative and qualitative data to be assessed (Mondal et al., 2010).

MATERIALS AND METHODS

The study area covers the approved boundaries if the cities Rasht as the Guilan province capital, located in the Guilan Plateau, and Anzali located in the northern part of the Guilan province along Caspian Sea coast. According to the yearly statistical report of the year 2000, the township includes one district with 2 rural divisions and 58 villages a map of the guilan region is illustrated in Figure 1. The average altitude of Anzali is about 20 m below the mean level (GWWC, 2010). A detailed description of the climate characteristics of Rasht and Anzali is presented in Table 1.

By considering the Guilan province’s climate conditions from different points of view such as precipitation, humidity, water resources, temperature, vegetation cover, five options of sludge disposal are studied: sludge composting, co-composting (composting with municipal solid waste), grass land application, sanitary landfill and incineration by sludge incinerator. These disposal methods are efficient but have negative effects on environment and public health (Taiwo, 2011). In this study, the environmental impact of these options on different environmental components is studied, with the positive and negative effects of each disposal option being evaluated

The RIAM method is used for the assessment of sludge disposal methods in the cities of Rasht and Anzali. The important criteria for assessment of different sludge disposal methods are selected and analysed. The impacts of disposal methods are evaluated according to the environmental, social and economical components. For each component, a score is determined, which provides a measure of the impact expected from the component. Each criterion is weighted based on their importance and

Table 1. Climate characteristics of Rasht and Anzali.

Parameter	Rasht	Anzali
Maximum absolute temperature	ºC +48	-
Minimum absolute temperature	ºC -11	-
Average daily temperature	-	ºC + 16.1
Average Maximum relative humidity	100%	-
Average Minimum relative humidity	26.6%	-
Average relative humidity at 6.30	-	90%
Average relative humidity at 12.30	-	75%
Average yearly precipitation	1409. 2 mm	1848 mm
Prevailing wind direction	From west to east and northeast to south west	From north east to south west
Maximum wind velocity	20 m/s	29.8 m/s

magnitude, and hence, all criteria are converted to single a quantitative parameter.

The important assessment criteria fall into two groups, viz:

(i) Criteria that are of importance to conditions that can individually change the score obtained. These criteria show the importance and domain of environmental impacts.
(ii) Criteria that are of value to the situation, but should not individually be capable of changing the score obtained. These criteria show the type of environmental impacts.

To determine the score for each environmental component the following equations are used:

$$(A1) \text{ ı } (A2) = At \quad (1)$$
$$B1 + B2 + B3 = Bt \quad (2)$$
$$(At) \text{ ı } (Bt) = ES \quad (3)$$

where: A1 and A2 are the individual criteria scores for group A; B1, B2 and 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 environmental score for the each component of the each disposal option (Mondal et al., 2010). Table 2 shows the criteria that are used for the assessment of the different sludge disposal options.

To provide a more certain system of assessment and simpler understanding of the impact of each disposal option on the environmental component, the individual ES scores are banded together into ranges where they can be compared, as shown in Table 3.

Environmental components for the evaluation fall into four categories, which are defined as follows:

i) Physical - chemical: Covering all physical and chemical aspects of the environment.
ii) Biological - ecological: Covering all biological aspects of the environment.
iii) Social: Covering all human aspects of the environment, including cultural aspects.
iv) Economical: Quantitative identification of the economic consequences of sludge disposal. It should be noted that the higher the cost for sludge disposal, the lower score obtained.

The environmental components used in this study are similar to the study by El- Naqu (2005) on the environmental assessment of waste landfill using the RIAM method.

In order to employ the evaluation system, a matrix is produced for each disposal option, comprising of cells showing the criteria used, set for each defined component, and within each cell the individual criteria scores were set determined. Using Equations 1 to 3, the ES number is calculated and recorded. The disposal options can then be compared from all environmental components points of view and for each component alone. For example, all options can be compared from social or physical-chemical points of view without considering the economical and ecological components.

In order to collect the ideas of experts in the field of environmental sciences regarding the environmental impacts, a questionnaire was prepared on the basis of all components according to the matrix in Table 3 for each option. The questionnaire was addressed to all environmental experts in water and wastewater companies in Guilan, the municipality of Rasht and the health centre of the Guilan province. A guidance pamphlet was addressed to all experts for describing the mechanisms of sludge disposal impacts on environmental components. Table 3 shows the average points that are given to sanitary landfill as a sample. This matrix is completed for all other sludge disposal options and an option as no sanitary disposal. As shown in Table 4, there are 8 physical / chemical components, 4 biological /ecological components, 10 social / cultural components and 10 economical components in this matrix.

RESULTS AND DISCUSSION

Results of the assessment matrixes of the different disposal options are summarized in Figures 2 to 7. Environmental condition and score of each option is given from all environmental component points of view. These figures clearly show the environmental conditions of the disposal options, allowing for a simplified optimum and alternative selections.

The results of the environmental assessment of the landfill option are given in Figure 2. This option has 5 moderate positive effects and 4 positive effects. It can be seen that this option has no major and significant negative effects on the environmental components, other than the economic component, and has only 1 moderate negative effect on the social components. The RIAM method that was used for assessment of environmental impacts of waste disposal sites in Turkey shows that most of the impacts are class A (Baba, 2005), which is not same as used in this study. It must be considered that if gases generated in the in landfill are not controlled, this option will have low negative effect as shown in

Table 2. Assessment criteria (Mondal et al., 2010).

Description	Scale	Criteria
Important to national/international interests	4	
Important to regional/national interests	3	
Important to areas immediately outside the local condition	2	A1: Importance of condition
Important only to the local condition	1	
No important	0	
Major positive benefit	+3	
Significant improvement in status quo	+2	
Improvement in status quo	+1	
No change / status quo	0	A2: Magnitude of change / effect
Negative change in status quo	-1	
Significant disbenefit or negative change	-2	
Major disbenefit or negative change	-3	
No change / not applicable	1	
Temporary	3	B1: Permanence
Permanent	4	
No change / not applicable	1	
Reversible	2	B3: Reversibility
Irreversible	3	
No change / not applicable	1	
Non-cumulative / single	2	B3: Cumulative
Cumulative / synergistic	3	

Table 3. Conversion of environmental score to description parameter (kuitunen et al,2008).

Description of range bands	Range bands	Environmental score
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	0
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	−E	−72 to −108

Figure 2. Another notable point is the negative impact on the social component. This negative social effect is related to only the population near the landfill site, and hence, reduction of this negative impact will be probable.

Figure 3 shows results of the environmental assessment of the sludge composting option. It can be seen this option has positive effects on the physical-chemical and biological components, while the important negative effects of this option are on the social and economical components. Composting has 1 significant positive effect, 3 moderate positive effects and 7 positive effects. This option has no significant or moderate negative effects on the environmental components, other than the economical components, and only there are 4 negative effects on social component. The main negative impact is related to lack of public acceptance for the use

Table 4. An example of points given for the environmental component of the sanitary landfill matrix.

Environmental components	B_3	B_2	B_1	A_2	A_1	Description	ES
Physical-chemical component							
Disposal of wastewater treatment plant sludge	1	2	2	2	2	+C	20
Collection and treatment of leachate	3	2	2	1	2	+B	14
Surface water quality	1	2	3	2	2	+C	24
Ground water quality	3	2	2	-1	2	+B	-14
Soil quality	3	2	2	-2	2	-C	-28
Soil erosion an flood	2	2	3	1	3	+C	21
Air quality (toxic gases and particle)	3	2	2	0	3	N	0
Air quality (green house gases)	3	2	2	1	4	+C	28
Biological-ecological component							
Effect on land ecosystem	1	2	2	-1	2	-B	-10
Effect on aquatic ecosystem	1	2	2	0	3	N	0
Effect on flora	1	2	2	-1	2	-B	-10
Effect on fauna	1	2	2	-1	2	-B	-10
Social-cultural component							
Dwelled population near disposal site	1	2	2	-3	1	-B	-15
Problems from air pollution	1	2	2	0	1	N	0
Problems from noise	2	2	2	-3	1	-B	-18
Reuse of products	1	2	2	1	2	+B	10
Increase job demand	1	3	3	1	1	+A	7
Public health	1	2	2	3	2	+C	30
Problems from odor	2	2	2	-2	1	-B	-12
Knowledge and awareness	1	2	2	1	2	+B	10
Public acceptance	1	2	2	-2	2	-C	-20
Public participation	1	2	2	-1	1	-A	-5
Inter-organizational participation	1	2	2	0	3	N	0
Economical component							
Cost of equipment providing	1	3	3	-1	3	-C	-21
Cost of civil activities	1	3	3	-1	3	-C	-21
Cost of land acquisition	1	3	3	-3	3	-D	-63
Cost of transportation	1	3	3	-1	3	-C	-21
Cost of air pollution control	1	3	3	-1	3	-C	-21
Cost of ground water pollution control	1	3	3	-3	3	-D	-63
Cost of periodical monitoring	1	3	3	-1	3	-C	-21
Cost of pre-treatment	1	3	3	1	3	+C	21
Cost of sludge storage	1	3	3	1	3	+C	21
Cost of operation and maintenance (energy, personals and …)	1	3	3	-1	3	-C	-21

of the produced compost. Field inspections on solid waste compost confirm this subject. It should be noted that sludge composting must be considered as a disposal method even if the produced compost is not accepted by public. The comparison of the alternatives in the EIA report describes the method of composting as an important form of disposal because it greatly reduces sludge volume (UNU, 2006).

As shown in Figure 4, co-composting has many positive effects on all the environmental components. This option has 1 significant and 6 moderate positive effect on the environmental components, while only 2 negative and 2 low negative effects are seen. The main problems for this option are the low capacity of available composting factory in the city of Rasht and stability of inter-organizational participation. These problems can be solved through the execution of a composting factory development plan. It is demonstrated that co-composting

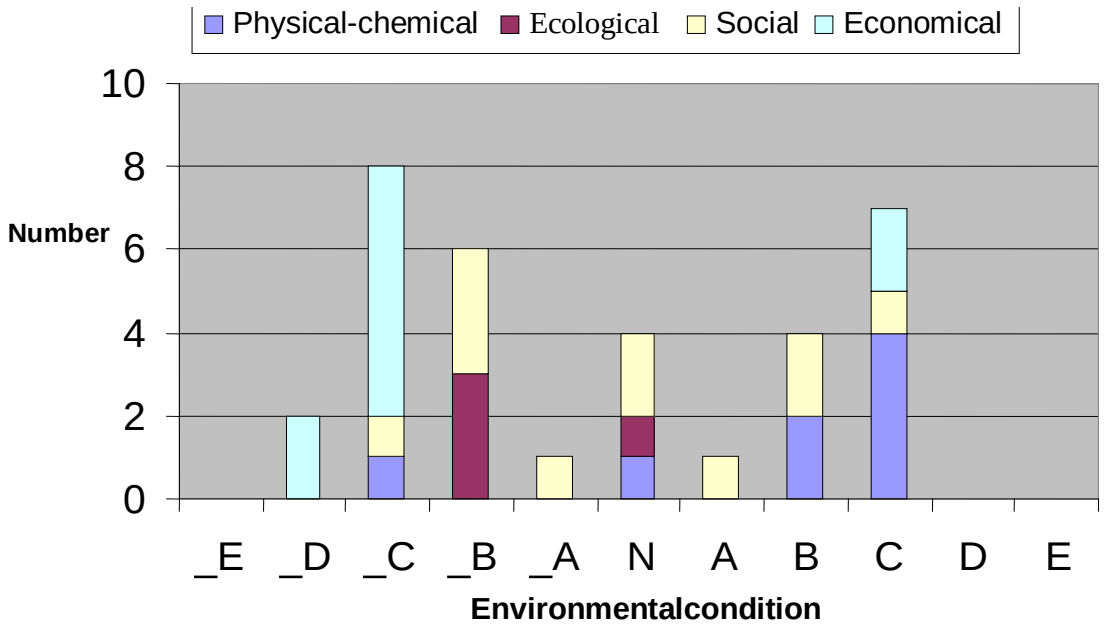

Figure 2. Summary of the assessment matrix for the landfill method.

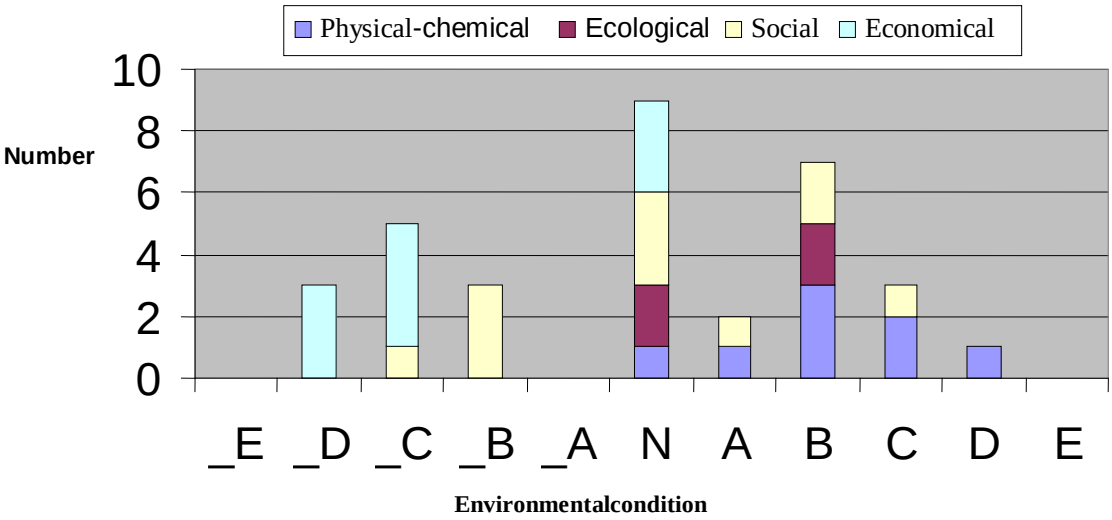

Figure 3. Summary of the assessment matrix for the composting method

is a proper method for disposal of sludge from industrial wastewater treatment plant such as textile industry (El-Hammadi et al., 2007).

It is clearly known that stabilised sludge by chemical or biological methods can be achieved based on the requirements of USEPA standards for class B and can be use as soil conditioner (Jamal et al., 2011). The results from the assessment of the option for land application of sludge in the grass land of the Guilan province are given in Figure 5. It can be seen that the main negative effects are related to the social components which is caused by periodical prevention of grazing in grass lands (public acceptability). The positive effects of this option on the environmental components are from soil quality and fertility enhancement of grass land, and increasing of the production of provender. With enhancement of vegetation covering, soil erosion and flooding will decrease. From the economical point of view, this option is better than other the other options, except co-composting.

This option has 1 significant positive effect on the physical-chemical components and 4 moderate positive effects on the physical-chemical and social components. There is 1 significant negative effect on social components. This significant negative effect arises from

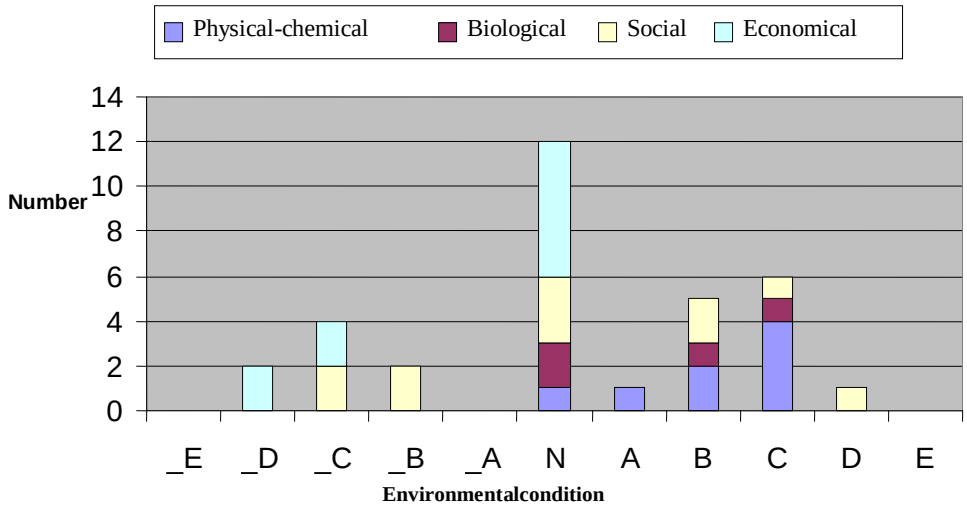

Figure 4. Summary of the assessment matrix for the co-composting method.

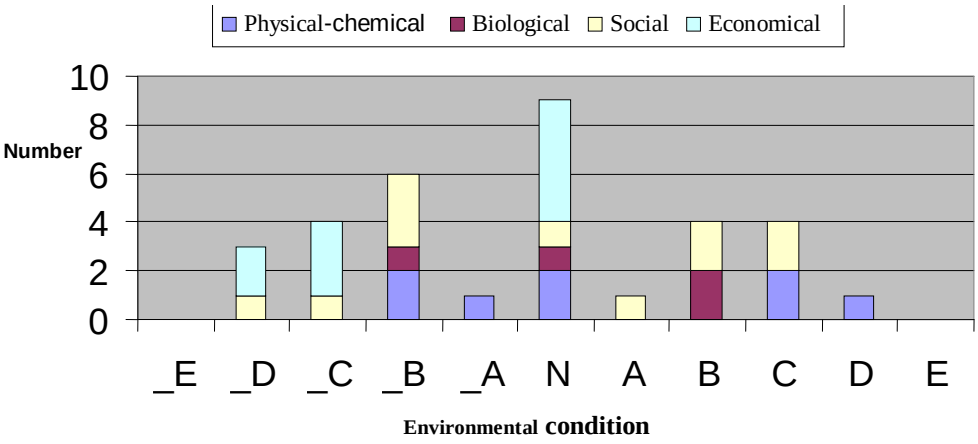

Figure 5. Summary of the assessment matrix for the land application method.

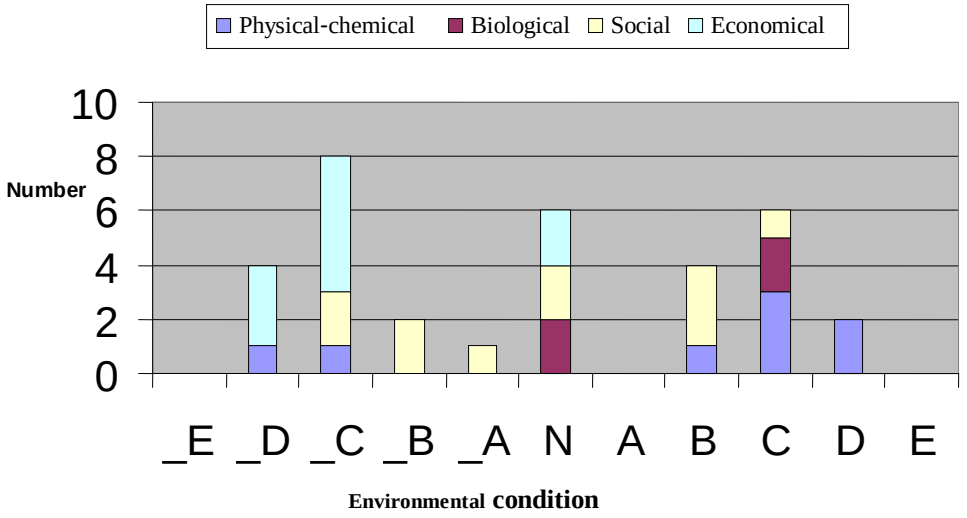

Figure 6. Summary of the assessment matrix for the incineration method.

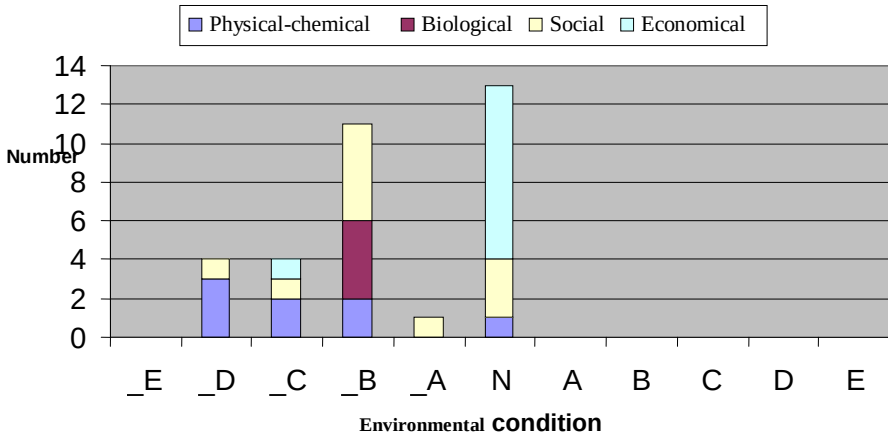

Figure 7. Summary of the assessment matrix for the lack of sanitary disposal method.

Table 5. Comparison of the options' effects on the biological –ecological components.

Results of assessment	+E	D+	+C	+B	+A	N	-A	-B	-C	-D	-E	Environmental condition
-3B						1		3				Landfill
+2B				2		2						Composting
C+B			1	1		2						Co-Composting
+B				2		1		1				Land application
2C			2			2						Incineration
-4B								4				Lack of sanitary disposal

Table 6. Comparison of the options' effects on the social-cultural components.

Results of assessment	+E	+D	+C	+B	+A	N	-A	-B	-C	-D	+E	Environmental condition
-B			1	2	1	2	1	3	1			Landfill
-B+A			1	2	1	3		3	1			Composting
D-C		1	1	2		3		2	2			Co-Composting
-D+C-B+A			2	2	1	1		3	1	1		Land application
-C+B-A			1	3		2	1	2	2			Incineration
-D-c-5B-A						3	1	5	1	1		Lack of sanitary disposal

probable public and organisational resistance against land application in grass land. Public education programmes and enhancement of inter-organisational participation can be useful to solve this problem.

As shown in Figure 6, the incineration of sludge option has 1 significant negative effect on the physical-chemical components and 2 moderate negative effects on the social components. These negative effects are caused by air pollution. The most important impact of incinerators on the environmental components of territory is due to gas emissions into the atmosphere (Lisi et al., 2007). On the other hand, the most positive effect on the physical-chemical components is related to incineration (2 significant and 4 moderate effects). It can be seen that the economical consequences of incineration is more than the other options, with the incinerator and periodical monitoring of exhausted gases being the most costly activities.

It should be noted that air pollution problems can be reduced or removed if there is efficient management system for sludge incineration system. It was reported that in a health risk assessment of incineration of waste, the main health risk is related to off gas from incinerators that must be controlled (Christopher, 2002).With attention to the technical potential in Guilan water and wastewater companies, the possibility of air pollution control is high.

Figure 7 shows that lack of a sanitary disposal system can be have many significant negative effects on all of the environmental components.

For better comparison of the disposal options, the environmental condition of each component for each option is reported in Table 4 to 7.

Based on the results of the assessment for options from physical-chemical component, the priorities of the

Table 7. Comparison of the options' effects on the economical components.

Results of assessment	+E	+D	+C	+B	+A	N	-A	-B	-C	-D	-E	Environmental condition
-2D-4c			3						6	2		Landfill
-3D-4C						3			4	3		Composting
-2D-2C						6			2	2		Co-Composting
-2D -2C						5			3	2		Land application
-3D-5C						2			5	3		Incineration
-D						9				1		Lack of sanitary disposal

Table 8. Comparison of the options' effects all the components, except economical.

Results of assessment	+E	+D	+C	+B	+A	N	-A	-B	-C	-D	Environmental condition
+3C-2B			5	4	1	4	1	6	2		Landfill
+D+2C+4B+2A		1	3	7	2	6		3	1		Composting
+D+4C+3B+A		1	6	5	1	6		2	2		Co-Composting
+3C-2B		1	4	4	1	4	1	6	1	1	Land application
+D+3C+2B-A		2	6	4		4	1	2	1	1	Incineration
-4D-3C-11B-A						4	1	11	3	4	Lack of sanitary disposal

options are; 1- composting, 2- incineration, 3- land application, 4- co-composting and 5- landfill.

By observing the Table 5 and the resultant of environmental condition of all options from biological ecological component points of view, priorities of options are as below:

1- Incineration, 2- Co-Composting, 3- Composting, 4- Land application and 5- Landfill.

By observing the Table 6 and the resultant of environmental condition of all options from social component points of view, priorities of options are as below: 1- Co-Composting, 2- Composting, 3- Landfill, 4- Incineration and 5- Land application.

Economical comparison of different options is given in Table 7.

It can be seen that from economical component point of view; priorities of options are as below:

1- Land application, 2- Co-Composting, 3- Landfill, 4- Composting and 5- Incineration.

Table 8 shows the environmental conditions of the disposal options without considering the economical component. The optimum option, which has the most positive effects for all the environmental components, is co-composting. In this option, there are no negative effects that cannot be outweighed against the positive effects. This option has 1 significant positive, 4 moderately positive, 1 positive and 1 slightly positive effect.

The second option is sludge incineration as shown the resultant of environmental condition for this option is 1 significant positive effect, 3 moderately positive effects, 2 positive effect and 1slightely negative effect.

The third option is co-composting. In the resultant of environmental condition for this option there are no negative effects. The resultant of this option shows 1 significant positive, 2 moderately positive, 2 positive and 2 slightly positive effects.

The fourth option is land application in grass land. The resultant of environmental condition for this option shows 3 moderately positive effects and 2 negative effects.

The fifth option is landfill. The resultant of environmental condition for this option shows 3 moderately positive effects and 2 negative effects. It should be noted that in environmental evaluation of landfill there was no significant negative effect.

Considering the economical components, other resultant of components will be obtained.

Table 9 shows the overall results of the assessment for all the disposal options. It can be seen that prioritisation of sludge disposal options has changed; 1- Co-composting, 2- Land application in grass land, 3- Landfill, 4- Composting, 5- Incineration.

Conclusion

As shown in this study, all the disposal options have many positive impacts on the environment in comparison with the lack of sanitary disposal. In comparison with each other, there are many advantages and disadvantages, with each option having different impacts on the environmental components. Therefore, the opinions of environmental experts from the Guilan water and wastewater companies about priority of the components have been very important for selection of the options. Generally, this study shows that co-composting

Table 9. Comparison of the options' effects all the components.

Results of assessment	+E	+D	+C	+B	+A	N	-A	-B	-C	-D	Environmental condition
-2D-C-2B			7	4	1	4	1	6	8	2	Landfill
-2D-2C+4B+2A		1	3	7	2	9		3	5	3	Composting
-D+2C+3B+A		1	6	5	1	12		2	4	2	Co-Composting
-2D-2B		1	4	4	1	9	1	6	4	3	Land application
-2D-2C+2B-A		2	6	4		6	1	2	8	4	Incineration
-4D-4C-11B-A						13	1	11	4		Lack of sanitary disposal

is the best recommended alternative for sludge disposal in the existing conditions.

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