SITE SELECTION CRITERIA FOR HAZARDOUS WASTE TREATMENT, STORAGE AND DISPOSAL FACILITY

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ABSTRACT

The Government of India has promulgated the Hazardous Waste (Management & Handling) Rules (HW (M&H)) in 1989 through the Ministry of Environment and Forests (MOEF) under the aegis of Environment (Protection) Act [E(P) Act], 1986. Also in order to encourage the effective implementation of these rules, the MOEF has further brought out the Guidelines for HW (M & H) in 1991. However, case studies reveal that, the options available for hazardous waste management (HWM) are not being efficiently utilized by the waste generators resulting in severe pollution of land, surface and ground water.

Treatment, Storage and Disposal Facility (TSDF) is a highly useful option for waste generators who could not bear the high costs involved in the infrastructural and land facilities required for the effective management of their hazardous waste(s). It is a unique concept, where the wastes are collected from the waste generators, treated as per their characteristics and finally disposed off. However, the selection of a suitable site for an effective functioning of TSDF is the key factor involved in the HWM. The site should be selected based upon several factors such as waste characteristics, site characteristics, public acceptance and prevailing laws & regulations. The various operations effecting the site selection are discussed. Emphasis is given to evaluation of impacts of TSDF on the local environment under EIA study. In view of the wide range of infrastructural and other associated requirements needed for site selection, construction and operation of TSDF, the impacts generated by it on the local environment become complex in nature. The various aspects likely to be effected during Construction, Operational and Final phases of the TSDF are identified. A *20 x 17* matrix is prepared to assess the impacts on these aspects. This matrix can be modified as per the local needs of the project.

Keywords: TSDF, Hazardous Waste, Site Selection Criteria, Site Sensitivity Indices, EIA Matrix.

NEED AND IMPORTANCE

There is a growing concern all over the world for the disposal of hazardous wastes generated from anthropogenic sources. The waste generators find it difficult to dispose their hazardous wastes without causing environmental disturbance, as very few appropriate disposal facilities are available. The Government of India has promulgated the Hazardous Waste (Management & Handling) Rules (HW (M&H)) in 1989 through the Ministry of Environment and Forests (MOEF) under the aegis of Environment (Protection) Act [E(P) Act], 1986. Also in order to encourage the effective implementation of these rules, the MOEF has further brought out the Guidelines for HW (M & H) in 1991.

The hazardous wastes need to be disposed off in a secured manner in view of their characteristic properties such as, toxicity, corrosivity, ignitability, reactivity and persistence. A wide range of health hazards has been attributed to their contamination. A number of options are available for the treatment and disposal of a variety of hazardous wastes (Wentz, 1995). However, case studies [Bruno, 1995; Bidwai, 1996; Sebastian, 1997; Madhavan Nair, 1999] reveal that, the options available for hazardous waste management (HWM) are not being efficiently utilized by the waste generators resulting in severe pollution of land, surface and ground water. This ineffective HWM can be attributed to:

- Absence of systematic qualitative and quantitative assessment (inventory) of hazardous wastes generated
- Improper storage and disposal practices of hazardous wastes
- Absence of proper treatment, storage and disposal facilities (TSDFs)

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The concept of TSDF is similar to that of a Common Effluent Treatment Plant operated for treatment of liquid effluents. At TSDF, the wastes are collected from the waste generators, treated as per their characteristics and finally disposed off. More than one unit operation may be employed for the treatment and disposal of the wastes at TSDF. However, the selection of a suitable site for an effective functioning of TSDF is the key factor involved in the HWM. The site should be selected based upon several factors such as waste characteristics, site characteristics, public acceptance and prevailing laws & regulations. The present study addresses the above aspects and focuses on:

- The salient features involved in the site selection criteria for TSDF
- The generation and discussion of a methodology in the form of a matrix useful for the assessment of impacts due to the construction and operation of TSDF

TSDF (Treatment, Storage and Disposal Facility)

TSDF is a highly useful option for waste generators who could not bear the high costs involved in the infrastructural and land facilities required for the effective management of their hazardous waste(s). The TSDF is established with the following objectives:

- Ensuring safe treatment, storage and disposal of hazardous wastes
- Helping the hazardous waste generators in its near vicinity to avail the facility for its designated purpose.

The three functional areas covered under TSDF, viz., treatment, storage and disposal are [Wentz, 1995]:

- **Treatment:** It refers to any process that changes the characterization or composition of a hazardous waste so as to render it less hazardous or that is capable of volume reduction or resource recovery.
- **Storage:** It refers to the temporary holding of hazardous wastes prior to treatment or disposal.
- **Disposal:** It refers to the deposit of a hazardous waste that might either safely re-enter the environment or be safely and securely disposed.

An ideal hazardous waste TSDF should meet [Wentz, 1995] the following requirements:

- Confirming with the land use planning and zoning of the local area.
- Easily accessible in all weather conditions to the type of transportation that will be used during the operation.
- Having secured safeguards against any potential air, surface water and ground water pollution.
- Acceptability with respect to the sensitivities of the residents
- Located where the operation is not likely to induce adverse impact on the environmentally sensitive resources.
- Large enough to accept and process hazardous wastes during the life of the operation.
- Cost-effective and economically profitable, while complying with applicable rules and regulations.

The facility siting should also incorporate the protection of human health, environment and property values in a community. The local public must be convinced that, a TSDF is needed and all reasonable steps will be taken to make it compatible with the environment and the location represents an equitable solution to a much larger problem. Landfill is the final disposal option of the wastes after they are subjected to treatment as per the various options shown in Fig. 1 [Wentz, 1995]. The landfill employed for hazardous waste disposal requires proper construction & maintenance and continuous monitoring [Tchobanoglous et al., 1993]. It should be provided with a run-off control, leachate collection and treatment, monitoring wells and a final cover over the entire landfill. The landfill design, construction, maintenance and operation play a **decisive role** in the site selection of a TSDF. In general, the TSDF should give importance to various aspects [Wentz, 1995; Lakshmi, 1999] during the following periods of its operation:

- Operational period
- Closure period
- Post-closure period

Ambient air quality, surface/ground water and leachate monitoring should be carried out during the operational period of TSDF and continued till the end of post-closure period. The ground water and leachate monitoring, in specific, is required where landfills, land treatment operations, surface impoundments etc. are located. This monitoring is necessary to determine the impact of TSDF on ground water resources. If ground water contamination is suspected, steps should be taken to assess its magnitude and rectify the problem. The closure period begins when the facility no longer accepts wastes. During this period, TSDF must completely process all on-site wastes and place a final cover over the landfill. The facility's equipment, structures and soil must be decontaminated or disposed off. A 30-year post closure period commences following the closure of TSDF. Besides the monitoring of items mentioned earlier, during this period, an overall monitoring scheme for the TSDF should also be included. The overall monitoring scheme covers aspects such as, working areas, hygienic conditions, access roads and whole geographical area of the facility for the cleanness, effectiveness and overall safety of TSDF. A fully trained manpower should be recruited for conducting the environmental monitoring and maintaining the records properly for ensuring any inspections and/or measures to be taken for improving the overall functioning of TSDF. Both the closure and post-closure requirements minimize the need for long-term maintenance and ensure control of any potential leakage of contaminants into the environment.

SITE SELECTION

The selection of an ideal site confirming with the above requirements is a difficult task. However, a few guidelines are reported [Lakshmi, 1999] for selecting a best site out of the available options. We propose that, the selection of a best site can be achieved by following the sequential steps of the methodology given below:

- General evaluation considering various features of the region/site such as climate, ecology, landuse, logistics, topography, soil properties, aesthetics etc.
- Site selection process through constraint mapping featuring Remote sensing applications and ranking of the available sites using site sensitivity indices
- Conducting Environmental Impact Assessment (EIA) studies and other techno-economic feasibility studies

The details of each are summarized below:

1. **General evaluation of site selection**

   This mode of evaluation is based on a number of factors such as physical features, ecological features, landuse features, logistics, climate and human values. The various aspects covered under these features are described in Table-1.

   The wastes would remain in the site for a long duration. The physical features of the site (Table-1) are useful in understanding the impact of the wastes on the local environment. The ecological features are necessary to understand their potential changes due to the TSDF. The land that is being used (i.e, landuse pattern) for agricultural/mining purposes should be given priority over TSDF. The employment potential generated and improvement in the access to both transport facilities and other utilities such as Hospitals, fire services etc., due to the TSDF are some of the likely benefits for the local public.

2. **Site selection criteria using constraint mapping**

   This method is used for eliminating unsuitable areas for narrowing down the site selection. Selected exclusion factors can be used for this purpose [Lakshmi, 1999]. The details of the site with respect to these features are mapped and superimposed over the base map of the region. These factors should be imposed along with other factors such as ecologically and otherwise sensitive areas, coastal areas, flood plains, highways, railways, major settlements etc. Remote sensing applications can be helpful in preparing the maps with specific objective as required by this method. The site can be selected from the regions excluding the zone covered by these factors. The exclusion factors are as follows:

   - Seismic risk zones
   - National parks/sanctuaries
   - Surface and subsurface mining
   - Coastal flood hazard areas
   - Coastal wetlands
   - Watersheds for public water supply
   - Critical recharge areas and sole source aquifers
   - Areas of high well yield

Table-1 *Aspects covered under General evaluation of site selection*

Physical features • Topography • Land stability • Seismic stability • Surface soils • Surface water and streams • Subsurface geology & aquifers	***Human values*** • Landscape • Recreation • Historical and archaeological monuments • Population density • Employment opportunities • Health status of population
Ecological features • Flora & fauna • Conservation value • Habitat	***Climate*** • Wind direction • Temperature • Moisture
Landuse features • Development potential • Landuse designation • Agricultural use • Transportation corridor • Extraction industries/mining	***Logistics*** • Proximity to users • Transport access • Availability of utilities (Hospitals, fire services etc.) • Adjacent land use

3. Site sensitivity indices

The site sensitivity indices are prepared for ranking the available sites with respect to *thirty four* (34) selected attributes. These attributes are based on the migration, characteristics, waste management practices for the wastes to be disposed at the TSDF. They are grouped under:

- Receptor related attributes
- Pathway related attributes
- Waste characteristics related attributes
- Waste management practices related attributes

The details of individual attributes are given in Table-2. The sensitivity index for each attribute is evaluated [Lakshmi, 1999] on a four-level sensitivity scale ranging from 0 to 1 (0.0-0.25, 0.25-0.5, 0.5-0.75, 0.75-1.0). The aspects to be considered for attribute measurement are identified depending on the importance of the attribute. Based on the field data available, this attribute can be graded on the four level scale for the particular site. A total of 1000 points are divided among the above listed four criteria of attributes @ 320, 280, 220 & 180 respectively using *Delphi* technique. Each of the 34 attributes is given weights based on the magnitude of its impact. The value of the sensitivity index multiplied by the corresponding weightage would give the attributed score for each attribute. In the same way, score for all the attributes will be calculated and final attributed score for the site is obtained. This score is compared with the similar scores of the other sites available and all the sites are ranked as per the scores with the least score site given the top ranking. The total scores (out of 1000) can thus be interpreted (Lakshmi, 1999] in terms of the sensitivity of the site as follows:

- Score below 300 : *Very low sensitivity*
- Score between 300 – 450 : *Low sensitivity*
- Score between 450 – 600 : *Moderate sensitivity*
- Score between 600-- 750 : *High sensitivity*
- Score above 750 : *Very high sensitivity*

For example an attribute, distance to nearest drinking water source, carrying a weightage of 60 points, can be graded based on the following four options:

- Greater than 5000 m (*sensitivity scale : 0.0 – 0.25*)
- 2500 to 5000 m (*sensitivity scale : 0.25 – 0.5*)
- 1000 to 2500 m (*sensitivity scale : 0.5 – 0.75*)
- Less than 1000 m (*sensitivity scale : 0.75– 1.0*)

Table-2 *Attributes considered for calculation of site sensitivity indices*

Receptor related	***Waste characteristics related***
• Population within 500 meters • Distance to nearest drinking water source • Distance nearest off site building • Presence of major transportation routes • Landuse/zoning • Critical environments • Use of site by nearby residents	• Toxicity • Radioactivity • Persistence • Ignitability • Reactivity • Corrosivity • Solubility • Volatility
Pathway related	***Waste management practice related***
• Distance to nearest surface water • Depth to ground water • Type of contamination • Soil permeability • Bedrock permeability • Depth to bedrock • Susceptibility to erosion & run-off • Climatic features with respect to air pollution • Susceptibility to seismic activity • Precipitation effectiveness index	• Physical state • Hazardous waste quantity per annum • Waste incompatibility • Co-disposal with municipal wastes • Use of liners • Leachate treatment • Site security • Safety measures • Incineration with off-gas cleaning

Based on the field data, it is found that, the nearest distance to drinking water source is 2500 m. This gives a site sensitivity index of 0.25. The attributed score for this parameter will be 0.25 x 60 = 15.0.

4. Site selection by conducting EIA (Environmental Impact Assessment) studies

EIA serves as a valuable tool for identification, prediction and evaluation of impacts due to the proposed TSDF at a particular site. It evaluates the potential impacts, both beneficial and adverse, of the project i.e., TSDF on the environmental system. There are different methodologies available [Venugopalan, 1986; Kulkarni, 1996] for the assessment of the impacts under the EIA study. However, the State Government or a person authorized by it will do the final selection of the site as per the Guidelines to HW (M&H) Rules issued by the MOEF (from time to time).

Evaluation of impacts is one of the important features of EIA. It summarizes and evaluates the impacts generated by taking up the TSDF. In view of the wide range of infrastructural and other associated requirements needed for site selection, construction and operation of TSDF, the impacts generated by it on the local environment become complex in nature. During the above stages of TSDF, the following phases are identified to take place:

- Construction phase
- Operational phase
- Final phase

The above phases may affect the local environmental attributes such as air, water, soil, landuse, human beings and flora & fauna. Aspects such as access roads and services, site preparation, diversion of watercourses, infrastructural development, earth moving activities, traffic movements, leachate and gas control and/or treatment, re-vegetation, greenbelt development, monitoring etc. are addressed under the above activities. The local changes such as, public health and safety, population changes, changes in landscape, gaseous emissions, emission of water pollutants and local drainage, potential changes in local flora & fauna etc are also considered.

In order to account for the changes of all the factors discussed above, a matrix of size *20 x 17* is developed (Table-3) for evaluating the impacts due to implementation of the TSDF. Each cell in the matrix refers to relation between specific project activity and the corresponding environmental attribute. The matrix reflects two assumed conditions:

- The conditions in the study zone
- The likely impacts which may occur after adoption of all the proposed control and safety measures envisaged in Environmental Management Plan highlighted in the EIA study

The impacts may be graded on a simple scale of 1 to 4 indicating very slightly, slightly, moderate and significant nature respectively. The beneficial and adverse impacts may be denoted by (+) and (-) scales respectively. The above format *(20 x 17)* of the matrix can be modified as per the local needs. Similarly, the grading of the scales can also be altered depending upon the degree of accuracy required.

For example, during the construction phase, the impact of providing access roads and services on flora & fauna can be predicted as, marginal adverse impact depending upon road alignment. Based on this prediction, an impact score of *(–1)* can be allotted to flora & fauna under access roads and services during construction phase. Similarly, leachate collection and treatment during operation phase is expected to induce *status-quo* impact on water environment. However, considering any minor imbalances in the process, an adverse impact score of *(–1)* can be allotted under water environment. The rest of the parameters can be similarly worked out.

SUMMARY AND CONCLUSIONS

TSDF is a unique concept, where the wastes are collected from the waste generators, treated as per their characteristics and finally disposed off. It is similar to that of a Common Effluent Treatment Plant operated for treatment of liquid effluents. More than one unit operation may be employed for the treatment and disposal of the wastes at TSDF. However, the selection of a suitable site for an effective functioning of TSDF is the key factor involved in the HWM. The site should be selected based upon several factors such as waste characteristics, site characteristics, public acceptance and prevailing laws & regulations. The various operations effecting the site selection are discussed. Emphasis is given to evaluation of impacts of TSDF on the local environment under EIA study. In view of the wide range of infrastructural and other associated requirements needed for site selection, construction and operation of TSDF, the impacts generated by it on the local environment become complex in nature. The various aspects likely to be effected during Construction, Operational and Final phases of the TSDF are identified. A *20 x 17* matrix is prepared to assess the impacts on these aspects. This matrix can be modified as per the local needs of the project.

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	Effects on	**Human, flora & fauna**						**Landuse**		**Land**		**Water**		**Air**			
Phase	**Activities**	Noise	Public health & safety	Population change	Associated development#	Traffic#	Flora & fauna	Agriculture	Appearance and landscape	Geological	Physical	Pollutants	Drainage	Climate	Odours	Particulte matter	Emissions
	Access roads and services	-1	0	0	1	-1	-1	-1	-1	-1	-1	0	0	0	0	-1	0
	Site preparation	-1	0	0	0	-1	-1	0	-2	-1	-2	0	0	0	0	-1	0
	Diversion of water courses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Landfill cell construction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0
	Infrastructure	-1	0	0	1	-1	0	0	0	0	0	0	0	0	0	0	0
	Earthmoving	-1	0	0	0	-1	0	0	-2	-1	-2	0	0	0	0	-1	0
	Traffic movements	-2	-1	0	2	-2	0	0	0	0	0	0	0	0	0	-1	-1
	Waste unloading	-1	0	0	0	0	0	0	0	0	0	0	0	0	-2	-1	-1
	Pretreatment	-1	-1	0	0	0	-1	-1	0	0	0	-1	-1	-1	-2	-1	-2
	Waste compacting	-1	0	0	0	0	0	0	0	1	1	0	0	0	-2	-1	-1
	Daily cover spreading	0	0	0	0	0	0	0	2	1	1	0	0	0	1	0	0
	Leachate	0	-1	0	0	0	-1	0	0	0	0	-1	0	0	-2	0	0
	Gas	0	-2	-2	0	0	0	-1	0	0	0	-2	0	-1	-3	0	-1
	Soil replacement	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0
	Revegetation	0	0	0	2	0	2	0	2	1	1	1	1	1	0	1	1
	Greenbelt	1	0	0	0	0	2	0	3	1	1	1	1	2	0	1	1
	Leachate	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0
	Gas	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0
	Aftercare	0	1	0	0	0	1	0	2	1	1	0	0	1	0	0	0
	Monitoring	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0

Legend

Construction phase
Operation phase
Final phase

Nature of Impact

+ Beneficial
- Adverse

Scale

0 No impact/no change in status
1 Very slightly
2 Slightly
3 Moderate
4 Significant