HAZARDOUS WASTE MANAGEMENT IN INDIA

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ABSTRACT

Disasters occur due to both the natural and man-made activities. Hazards and Disasters are categorized into four groups, viz., Natural events, Technological events, Man-made events and Region-wise events. The adverse impacts caused due to the indiscriminate disposal of Hazardous Wastes (HWs) come under the category of Environmental Disasters. Hazardous Waste Management (HWM) is a very important issue and is assuming significance globally. There is no proper secured landfill facility available in India to dispose of Hazardous Waste (HW) till 1997. Very few industries in India, mostly in large scale and a few in medium scale, own proper treatment and disposal facilities. A common waste treatment and disposal facility such as Treatment, Storage and Disposal Facility (TSDF) for management of HWs generated from industries, is one of the useful options under such conditions. Few Guidelines issued by Ministry of Environment and Forests under Hazardous Wastes (Management & Handling) Rules, 1989 promulgated under Environment (Protection) Act, 1986 are available in India for selection of best site for TSDF. The planning for HWM comprises of several aspects ranging from identification and quantification of HW to development and monitoring of TSDF. This paper focuses on the basic steps involved in the Comprehensive HWM. The physical models developed by the authors for ranking of TSDF sites based on the Guidelines available are discussed. The current status in India pertaining to generation of HW and the TSDF sites is also addressed.

INTRODUCTION

Disasters occur due to both the natural and man-made activities (Khare, 2001). A hazard is a rare or extreme event that adversely impacts human life, property, or activity. No human settlements are free from the risk of natural hazards; therefore it is vital that researchers and decision-makers have access to all available hazards information (NGDC, 2003). E&DM (2003) classified the Hazards and Disasters into four categories viz., Natural events, Technological events, Man-made events and Region-wise events (Refer Table-1). The adverse impacts caused due to the indiscriminate disposal of Hazardous Wastes (HWs) come under the category of Environmental Disasters. For example, in 1982, 2242 residents are evacuated after dioxin is found in soil in Missouri, U.S.A. In 1996-97, 265354 tonnes of soil and other dioxin-contaminated material from Times Beach (Missouri, U.S.A) and 26 other sites in eastern Missouri had been incinerated (E&DM, 2003). Release of Methyl Isocyanate (MIC) gas in Bhopal (1984) caused a severe disaster in India (Banerjee, 2001; E&DM, 2003).

Table-1: Types of Hazards and Disasters

S.No.	Types of Hazards & Disasters	Events
1	Natural Events	Avalanches, Cyclones, Droughts, Dust/Sand storms, Earth Quakes, Epidemic Diseases, Famines, Floods, Heat waves, Hurricanes, Landslides/Mud slides, Lightening storms, Tornadoes, Typhoons, Volcanic eruptions, Wild-land fires.
2	Technological Events	Environmental Disasters, Fire and Explosion, Accidents (Industrial, Nuclear, Radiological, Transportation), Dam failures.
3	Man-made Events	Bio-Terrorism, Spreading Chemical Agents, Mass Hysteria, Sabotage, Assassinations, Vandalism etc.
4	Region-wise Events	Events specific to a region such as India.

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There is a growing concern all over the world for the safe disposal of HWs generated from anthropogenic sources. HWs can be classified (Babu and Gupta, 1997) into- (i) Solid wastes (ii) Liquid wastes (iii) Gaseous wastes (iv) Sludge wastes. HPC (2001) defines HW as any substance, whether in solid, liquid or gaseous form, which has no foreseeable use and which by reasons of any physical, chemical, reactive, toxic, flammable, explosive, corrosive, radioactive or infectious characteristics causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or environment, and should be considered as such when generated, handled, stored, transported, treated and disposed off. This definition includes any product that releases hazardous substance at the end of its life, if indiscriminately disposed off. The HW needs to be disposed off in a secured manner in view of their characteristic properties.

Severe pollution of land, surface and ground water may occur (Ramakrishna and Babu, 1999a; Rao, 1999) if the options available (Wentz, 1995; Parsa et al., 1996; Chakradhar et al., 1999) for Hazardous Waste Management (HWM) are not being efficiently utilized by the waste generators. As per the ideal industrial siting criteria in India, the industry should have enough land available within its premises for the treatment and disposal and or reuse/recycling of the wastes generated from it (Murali Krishna, 1995). However, very few industries in India own proper treatment and disposal facilities (Jeevan Rao, 1999). Mostly the large-scale industries and a few medium-scale industries (Ramakrishna and Babu, 1998), and none of the small-scale industries own the above facilities. Among the 1440 industries identified (as on 31.03.1996) in the country with a high potential for pollution, 203 industries (i.e., ~14%) are recorded as not having adequate facilities to comply with the regulatory standards for treatment and disposal of wastes (TEDDY, 1998). Financial, administrative, and infrastructural facilities are some of the reasons attributed for the above limitations. It is interesting to note that, till 1997, there is no secured landfill facility available in the country to dispose of HW (HPC, 2001).

Hazardous Wastes (HWs) are disposed off at Treatment, Storage and Disposal Facility (TSDF), a centralized location catering to the HW generated from the waste generators in the near vicinity. The TSDF will help the small and medium scale industries generating HW in disposing their wastes efficiently. Literature is available on the site selection and other related criteria of TSDF (Ramakrishna and Babu, 1999b; Lakshmi, 1999; Babu and Ramakrishna, 2000; Babu and Ramakrishna, 2003). The site selection criteria for a TSDF depend upon Receptors and Pathways of likely waste movement, Waste characteristics and Waste management practices (Guidelines, 1991). The planning for HWM comprises of several aspects ranging from identification and quantification of HW to development and monitoring of TSDF.

This paper focuses on the basic steps involved in the Comprehensive HWM (CHWM). The physical models developed by the authors (Babu and Ramakrishna, 2000; Babu and Ramakrishna, 2003) for ranking of TSDF sites based on the Guidelines available (Lakshmi, 1999; Guidelines, 1991) are also discussed. The current status in India pertaining to generation of HW and the TSDF sites is also addressed.

BASIC APPROACH IN HAZARDOUS WASTE MANAGEMENT

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. Under the HW (M&H) Rules, the hazardous wastes are divided into 18 categories. The details (HPC, 2001) are given in Table-2. Moreover, the role and responsibilities of the waste generator, state/central pollution controls boards and state Government is clearly defined. In order to encourage the effective implementation of these rules, the MOEF has further brought out the Guidelines for HW (M & H) Rules in 1991 (Maudgal, 1995; Ramakrishna and Babu, 1999b) giving the technical details of the principles of HWM covered under the HW (M&H) Rules, 1989.

However, the selection of a suitable site for an effective functioning of TSDF is the key aspect and depends upon several factors such as waste characteristics, site characteristics, public acceptance and prevailing laws & regulations. The facility siting should also incorporate the protection of human health, environment and property values in a community. Though the selection of an ideal site confirming with the above factors is a difficult task, few Guidelines are available (Guidelines, 1991) in India for selection of best site for the same purpose. In India, unauthorized dumping of HWs is however continuing and in most of the places, the HW is being utilized to fill the low-lying areas (HPC, 2001), which is not acceptable.

Table-2: Categories of Hazardous Wastes

Waste Category	Waste Type	Regulatory Quantities
1	Cyanide wastes	1 kg per year as cyanide
2	Metal finishing wastes	10 kg per year the sum of the specified substance calculated as pure metal
3	Waste containing water soluble chemical compounds of lead, copper, zinc, chromium, nickel, selenium, barium and antimony	10 kg per year the sum of the specified substance calculated as pure metal
4	Mercury, arsenic, thallium, and cadmium bearing wastes	5 kg per year the sum of the specified substance calculated as pure metal
5	Non-halogenated hydrocarbons including solvents	200 kg per year calculated as non-halogenated hydrocarbons
6	Halogenated hydrocarbons including solvents	50 kg per year calculated as halogenated hydrocarbons
7	Wastes from paints, pigments, glue, varnish, and printing ink	250 kg per year calculated as oil or oil emulsions
8	Wastes from Dyes and dye intermediates containing inorganic chemical compounds	200 kg per year calculated as inorganic chemicals
9	Wastes from Dyes and dye intermediates containing organic chemical compounds	50 kg per year calculated as organic chemicals
10	Waste oil and oil emulsions	1000 kg per year calculated as oil or oil emulsions
11	Tarry wastes from refining and tar residues from distillation or pyrolytic treatment	200 kg per year calculated as tar
12	Sludges arising from treatment of wastewater containing heavy metals, toxic organics, oils, emulsions, and spent chemicals, incineration ash	Irrespective of any quantity
13	Phenols	5 kg per year calculated as phenols
14	Asbestos	200 kg per year calculated as asbestos
15	Wastes from manufacturing of pesticides and herbicides and residues from pesticides and herbicides formulation units	5 kg per year calculated as pesticides and their intermediate products
16	Acid/alkali/slurry wastes	200 kg per year calculated as acids/alkalies
17	Off-specification and discarded products	Irrespective of any quantity
18	Discarded containers and container liners of hazardous and toxic wastes	Irrespective of any quantity

The essential elements of CHWM are briefly explained below:

- **Identification of Hazardous Waste Generation:** Identifying the HW generating industries is the first step. The HWs are classified under 18 categories and this information (Refer Table-2) may be used to screen the wastes generated and classifying them as HWs. However there are few observations that- there is a probability of occurrence of wastes in more than one category; and the above classification system does not give any information to understand the toxic characteristics of HW (Babu and Gupta, 1997). Few suggestions are also given to improve the classification system (Babu and Gupta, 1997). The data available with the State Industrial

Development Corporation (IDC), District Industries Centre (DIC), State Pollution Control Boards etc. may be utilized to identify the industries with a potential for HW generation.

- **Data Collection:** After identifying the HW generating sources, the inventory of the data pertaining to HW generation can be developed by conducting surveys through specially prepared questionnaires to each of the identified sources. This should be followed by field visits for data verification. It is essential that, the data that is obtained from the above options is verified from secondary data (either published data or available for another industry producing similar products). HW generation rates estimated from Plant capacity in Indian industries are available in literature (Bhoyar et al., 1996). This will help in identifying any misappropriate data and correcting in the database.
- **Waste Characterization:** The HW that is generated from the study region should be characterized. For this purpose, it is advisable that the samples may be collected from the waste generation source and analyzed in the laboratory. Literature data may be used in the absence of primary data. Detailed information on HW characterization pertaining to physical, chemical, and general characteristics; and properties pertaining to ignitability, corrosivity, reactivity, & toxicity is given by Babu and Gupta (1997).
- **Quantification of Hazardous Wastes:** The HWs are quantified based on their individual characteristics. The several options of compatibility of wastes with different characteristics should be studied and segregated. The quantity of HWs will be expressed in terms of each category for disposal (e.g. Recyclable, Incinerable, or Disposable etc). The wastes that are recyclable are used/waste oil, lead wastes, zinc wastes (HPC, 2001).
- **Identification of sites for disposal:** After quantifying the HW, and assessing the probable area requirements for its treatment, storage and disposal, the sites are to be identified. For this purpose, toposheets and/or remote sensing images of the study region may be used. The sites are to be physically verified in the field and to draw observations pertaining to the four different types of attributes (viz., Receptor related-, Pathway related-, Waste characteristics related-, and Waste management practices related-) available for ranking the sites. The site with a minimum score out of the available sites for ranking should be chosen as the site for establishing TSDF. Physical models are available in literature (Ramakrishna and Babu, 1999b; Babu and Ramakrishna, 2000; Babu and Ramakrishna, 2003) that give accurate results than the approximate methods available in Guidelines (1991) for ranking the sites for TSDF.
- **Conducting EIA:** The Environmental Impact Assessment (EIA) should be conducted in the site identified in the above step. The impacts from the project should be identified and public acceptance should be obtained for clearing the site for TSDF. Of the available options for impact prediction, Matrix method gives a better approximation of results as it focuses on cause-condition-effect relationship of the attributes involved in the activity (Ramakrishna and Babu, 1999b). A typical matrix model with a four-scale ranking is available in literature (Ramakrishna and Babu, 1999b) that is applicable for TSDF projects, which is discussed in the later section.
- **Implementing TSDF Programme:** The TSDF programme should be implemented at the final designated site. The site should contain adequate provisions for storage, treatment (Stabilization, Incineration etc.) and final disposal. Layouts for collecting the HW from the waste generation sources should be planned. The site should have the laboratory facilities to monitor the function of TSDF from time to time. Landfill is the final disposal option in TSDF. The leachate that has percolated should be treated in Effluent Treatment Plant (ETP) before disposal. Monitoring of ambient environmental qualities and TSDF performance should be done regularly during the post-closure period of landfill (30 years).

The details pertaining to above aspects in India are discussed below:

INDIAN SCENARIO OF HAZARDOUS WASTE MANAGEMENT

Identification of Hazardous Waste Generation

The HW generation in Indian States is given in Table-3 (HPC, 2001; SDNP, 2003). The data shows that the HW generation is maximum in Maharashtra (45.47%) followed by Gujarat (9.73%).

Minimum HW is reported in Chandigarh (0.0069%). The number of industries that generate HW are maximum in Maharashtra (30.38%) followed by Gujarat (22.93%). The data shows that, 13011 industries are generating **4415954** TPA of HW in India.

Table-3: Status of Hazardous Waste Generation in India (as on March 2000)

State / Union Territory	Code	Total Districts	Districts in which HW units located	Total units	Total HW generation TPA
Andhra Pradesh	AP	23	22	501	111098
Assam	ASS	23	8	18	166008
Bihar	BHR	55	12	42	26578
Chandigarh	CHN	1	1	47	305
Delhi	DEL	9	9	403	1000
Goa	GOA	2	2	25	8742
Gujarat	GUJ	24	24	2984	430030
Haryana	HAR	17	15	309	32559
Himachal Pradesh	HP	12	6	116	2159
Karnataka	KAR	27	25	454	103243
Kerala	KER	14	11	133	154722
Maharashtra	MAH	33	33	3953	2007846
Madhya Pradesh	MP	61	38	183	198669
Orissa	OR	30	17	163	341144
Jammu & Kashmir	JK	14	5	57	1221
Pondichery	PON	1	1	15	8893
Punjab	PUN	17	15	700	22745
Rajasthan	RJN	32	26	332	122307
Tamil Nadu	TN	29	29	1100	401073
Uttar Pradesh	UP	83	65	1036	145786
West Bengal	WB	17	9	440	129826
India	**IND**	**524**	**373**	**13011**	**4415954**

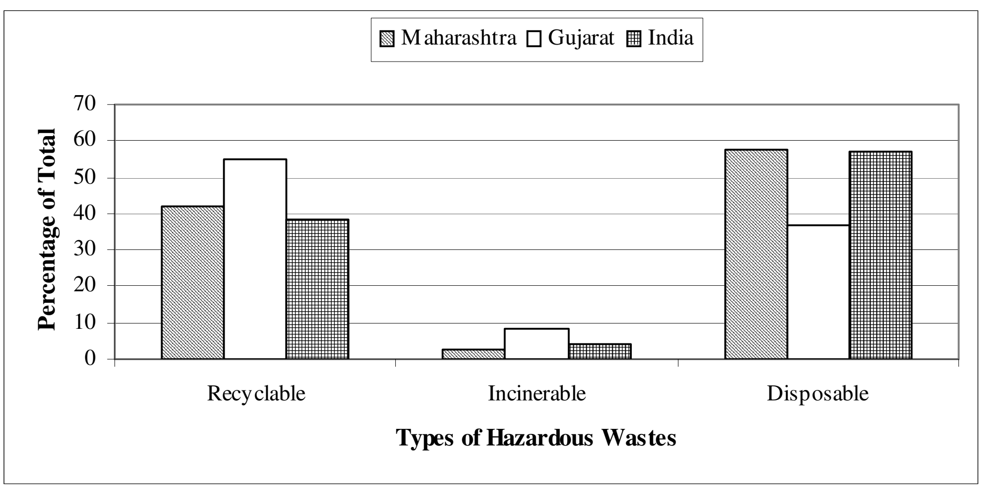

Fig.1: Comparison of Hazardous Waste characteristics in India

Waste Characterization

The HW in India is characterized and documented in literature (HPC, 2001; SDNP, 2003). The HWs are categorized into three groups viz., Recyclable, Incinerable, and Disposable. The details are given in Fig. 1 for Maharashtra, Gujarat and India (total). It can be noted from Fig.1 that, the HW generation trends in Maharashtra and India (total) are similar. The quantity of disposable HW (inorganic in nature to be disposed off in landfill) is high compared to the other two categories.

Quantification of Hazardous Wastes

The quantity of HW generation reported in India is 4415954 TPA from 373 districts out of 524 districts (Refer Table-3). According to one estimate (SDNP, 2003), the land required to dispose 5.3 million tones of HW in an engineered landfill, assuming the average density of waste to be around 1.2 tonnes/m^3 and the depth of the landfill 4 m, would be around 1.08 km^2 every year. This information may be applied to future waste projections to arrive at future land requirements for the disposal of hazardous waste.

Identification of sites for disposal

The number of sites identified for disposal of HW in India is 89 out of which 39 sites are notified. The State/Union Territory wise status (HPC, 2001) of identification and notification of sites for disposal is given in Fig. 2.

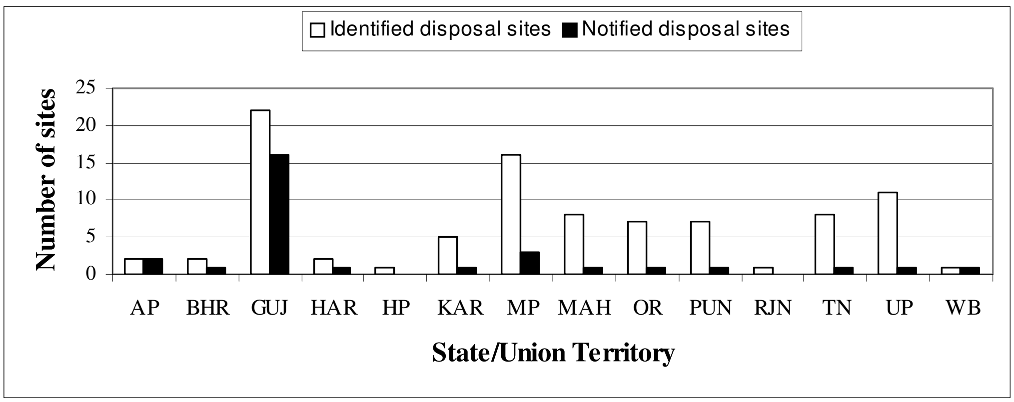

Fig.2: Status of Identified and Notified disposal sites in India

The sites are ranked using a ranking methodology given in Lakshmi (1999) and Guidelines (1991). The Site Sensitivity Indices (SSIs) 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. The details of individual attributes are given in Table-4.

The Sensitivity Index (SI) 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 four criteria of attributes @ 320, 280, 220, & 180 respectively using *Delphi* technique (Refer Table-4). Each of the 34 attributes is given weights based on the magnitude of its impact. The value of the SI 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*

Table-4: Attributes considered for calculation of site sensitivity indices

Receptor related (320)	Waste characteristics related (220)
▪ Population within 500 meters ▪ Distance to nearest drinking water source ▪ Distance nearest off site building ▪ Presence of major transportation routes ▪ Land use/zoning ▪ Critical environments ▪ Use of site by nearby residents	▪ Toxicity ▪ Radioactivity ▪ Persistence ▪ Ignitability ▪ Reactivity ▪ Corrosivity ▪ Solubility ▪ Volatility
Pathway related (280)	**Waste management practice related (180)**
▪ 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

A close examination of the options for ranking the sites has resulted in the following observations:

- The upper and lower limits for few attributes are not clearly defined.
- The sensitivity scale distribution for some of the selected attributes is not clear, and also non-linear when overall distribution is considered.
- The error/ambiguity in the prediction of SSI could lead to erratic ranking of the site designated for TSDF.

Twelve attributes out of 34 attributes are identified having the above limitations. They are listed in Table-5. A model based on Regression analysis is developed to address the above limitations. The data given in Guidelines (Guidelines, 1991) is taken as reference for the entire analysis (Babu and Ramakrishna, 2000; Babu and Ramakrishna, 2003).

- The analysis is carried out taking each attribute, case by case.
- Regression analysis is carried out to find out the Best-Fit Mathematical Model (BFMM) suitable for the data points of each attribute. Additional points are also generated by plotting graphs wherever necessary, for accurate fitting.
- An analysis is carried out by considering Linear Interpolation Among the Intervals (LIAI) (i.e., 0.25-0.5 & 0.5-0.75) specified in the Guidelines for all the data points.
- An additional analysis is also carried out for cross-checking by considering an Overall Linear Distribution Model (OLDM) of all the data points i.e., linear variation from 0.25-0.75.
- The above three analyses viz., BFMM, LIAI and OLDM are compared and conclusions are drawn.

The accuracy of the BFMM predictions is verified using Standard Deviation (SD) with respect to the expected value (i.e., 0.25, 0.5, & 0.75). The results of BFMM (Babu and Ramakrishna, 2000; Babu and Ramakrishna, 2003) are given in Table-6. The results indicated that-

- Accuracy improvement on estimation of SSI using the proposed BFMM over the assumed linear interpolation among the intervals of the data points.
- The upper and lower limits for prediction of SSI can be clearly identified.
- The erratic prediction of SSI can be minimized. This is important in order to avoid an improper representation of attributed scores (on the same basis) for ranking of available sites. It may project relatively unfavorable sites to be a better option.
- Very low values of SD (zero to 0.0297) are obtained for the twelve attributes considered. The accuracy of the BFMM results is better than the other two models viz., LIAI and OLDM.

Table-5: Details of selected attributes for modeling the SSI values

S.No.	Attribute	Category related to
1	Distance to nearest drinking water source	Receptor
2	Distance to nearest off-site building	Receptor
3	Population within 500 meters	Receptor
4	Distance to nearest surface water	Pathway
5	Depth to groundwater	Pathway
6	Depth to bedrock	Pathway
7	Soil permeability	Pathway
8	Precipitation effectiveness index	Pathway
9	Radioactivity	Waste characteristics
10	Ignitability	Waste characteristics
11	Volatility	Waste characteristics
12	Hazardous waste quantity per annum	Waste management practice

Table-6: Regression analysis based Best-Fit Mathematical Models (BFMMs) developed for the selected attributes

S. No.	Attribute	BFMM	Coefficients of BFMMs
1	Distance to nearest drinking water source	$y = (a + bx + cx^2 + dx^3)$	a = 1; b = -0.000291667; c = 4.5 x 10^{-8}; d = -3.33334 x 10^{-12}
2	Distance to nearest off-site building	$y = (a + bx + cx^2)$	a = 0.9; b = -0.000316667; c = 3.33333 x 10^{-8}
3	Population within 500 meters	$y = (a + bx + cx^2 + dx^3 + ex^4 + fx^5 + gx^6 + hx^7 + ix^8 + jx^9)$	a = -0.00436766; b = 0.00328853; c = -7.09652 x 10^{-6}; d = 8.88113 x 10^{-9}; e = -6.66002 x 10^{-12}; f = 3.10438 x 10^{-15}; g = -9.04904 x 10^{-19}; h = 1059822 x 10^{-22}; i = -1.55626 x 10^{-26}; j = 6.36894 x 10^{-31}
4	Distance to nearest surface water	$y = (a + bx + cx^2 + dx^3 + ex^4 + fx^5 + gx^6 + hx^7 + ix^8)$	a = 1; b = -0.00062248; c = 2.77587 x 10^{-7}; d = -7.02274 x 10^{-11}; e = 1.03965 x 10^{-14}; f = -9.20228 x 10^{-19}; g = 4.79102 x 10^{-23}; h = -1.35258 x 10^{-27}; i = 1.59708 x 10^{-32}
5	Depth to groundwater	$y = (a + bx + cx^2)$	a = 0.9; b = -0.0316667; c = 0.000333333
6	Depth to bedrock	$y = (a + bx + cx^2)$	a = 0.87605; b = -0.0439076; c = 0.000630252
7	Soil permeability	$y = (a + bx + cx^2 + dx^3)$	a = 1; b = -1.55952; c = -1.07143; d = 2.38095
8	Precipitation effectiveness index	$y = (a + bx + cx^2)$	a = -0.0716553; b = 0.0116374; c = -4.06901x 10^{-5}
9	Radioactivity	$y = (a + bx)$	a = 0.125; b = 0.125
10	Ignitability	$y = (a + bx)$	a = 0.928571; b = - 0.00714286
11	Volatility	$y = (a + bx + cx^2)$	a = 0.248825; b = 0.0117553; c = -6.83335x10^{-5}
12	Hazardous waste quantity per annum	$y = (a + bx + cx^2)$	a = 0.154762; b = 0.000392857; c = -4.7619x10^{-8}

The BFMM is found to be **superior** in terms of *accuracy, simplicity, clarity, and reliability* to the other two assumptions (OLDM and LIAI) of calculating the SSI values.

Conducting EIA
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, land use, 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.

Ramakrishna and Babu (1999b) developed a matrix suitable for TSDF projects based on the above discussed criteria. The size of the matrix is **20 x 17**. Each cell in the matrix refers to relation between specific project activity and the corresponding environmental attribute. 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 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.

Implementation of TSDF
The TSDF should be properly designed based on the HW expected at the site. The typical layout available in literature (Babu and Ramakrishna, 2000) may be used as a helping tool in this aspect. Periodical monitoring of the site should be carried out during the post-closure period. The monitoring scheme includes the ambient environmental quality and different activities pertaining to the direct and indirect operation of TSDF such as Amenity items, Site inspections, Habitat survey, Aftercare measures, and future planning etc.

SUMMARY AND CONCLUSIONS

Proper treatment, storage prior to treatment or disposal and safe disposal of HWs is the need of the hour. However, the site(s) to be selected for this purpose should fulfill certain criteria. The methodology of site selection may differ from country to country. There is no proper secured landfill facility available in India to dispose of HW till 1997. Guidelines are available in India for Management and Handling of HWs. Ranking of the sites for selecting them to be used in HW disposal (i.e., TSDFs) is an important issue. Unsuitable sites may be projected as suitable sites if the available guidelines are not clearly specified. The methodology for a Comprehensive HWM (CHWM) is presented in this paper and the current status in India pertaining to each of the elements of CHWM is discussed. The physical models suggesting improvements to the existing guidelines available for ranking the sites for TSDFs are presented.

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