A DECISION MAKING TOOL FOR DUMPSITE REHABILITATION IN DEVELOPING COUNTRIES

J. KURIAN*, S. ESAKKU*, R. NAGENDRAN* AND C. VISVANATHAN**

**Centre for Environmental Studies, Anna University, Chennai – 600 025, India*
***Environmental Engineering and Management Program, Asian Institute of Technology, Post Box 4, Pathumthani 12120, Thailand*

SUMMARY: This paper presents an Integrated Risk Based Approach (IRBA) for developing a decision-making tool for dumpsite rehabilitation including sites with high health risk, maximum environmental impacts and sensitive public concerns. Attributes to be considered for decision-making were selected based on literature, observations on activities and investigations in and around a few dumpsites in Asia, pollution, health risks and social impacts of the attributes and consultation with experts. The attributes fall into three categories, with weightage assigned to each attribute following the pair wise comparison method and sensitivity index on a scale of 0 to 1 based on attribute measurement. Validation of the tool done in respect of two local dumpsites indicates its usefulness as a decision making tool for prioritizing actions related to dumpsite rehabilitation. Detailed investigations and regulatory approval may be required as per the respective national or local legislations.

1. INTRODUCTION

Rapid population growth and urbanization in developing countries have led to the generation of enormous quantities of municipal solid wastes (MSW) and consequential environmental degradation. Safe and reliable disposal of municipal solid wastes and residues is an important component of integrated waste management. Open dumping of MSW, which is practiced by about three-fourths of the countries and territories in the world is a primitive stage of waste disposal (Rushbrook, 2001). The open dumps or dumpsites cause degradation of the environment since they are susceptible to open burning, groundwater pollution and exposed to scavengers and disease vectors. Problems of shortage of cover, lack of leachate collection and treatment, inadequate compaction, poor site design, and ragpickers invasion are common. Growing concerns about public health, environmental quality and the risks associated with the existing dumps make it almost impossible to site new landfills in many parts of the world. This calls for an integrated approach for sustainable management of dumpsites and landfills. At present, there are only limited resources for upgrading these dumpsites. Lack of technical competence and limited funds to operate and maintain land disposal sites compound the problem and delay the execution of work. Resource limitations often dictate that the detailed assessment and rehabilitation action be restricted to those sites considered to be most risky. Assessing the

Proceedings Sardinia 2005, Tenth International Waste Management and Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 3 - 7 October 2005

relative health and environment hazards posed by the dumpsites existing throughout the developing countries could help prioritize, plan and initiate dumpsite rehabilitation. Identifying the risk factors of concern will allow a community to target its efforts to minimizing both the risk potential of the landfill and the cost.

This paper presents an Integrated Risk Based Approach (IRBA) for developing a decision-making tool for dumpsite rehabilitation. The approach provides higher priority to dumpsites with high health risk, maximum environmental impacts, minimum rehabilitation costs and sensitive public concerns.

2. DUMPSITE REHABILITATION AND ENVIRONMENTAL RISKS

Reclamation and Rehabilitation of dumpsites as tools for sustainable land filling have been in vogue throughout the world for the last 50 years (Cossu *et al*., 1996, Hogland *et al*., 1996). The process of rehabilitating a dumpsite into a sustainable landfill is a phased activity, which depends on the risk posed by each dump and its financial aspects (Rushbrook, 2001; Kurian Joseph et al, 2004). To determine whether to rehabilitate and close or remediate, upgrade and operate a dumpsite, the environmental risks posed by it must be assessed. These may involve technical investigations and environmental impact assessments (EIAs) including consultation with the interested and affected parties, specifically the adjacent communities.

The perception of risk is central to the fear, which the public frequently associates with the waste storage/disposal facility. Typically, risk assessment process is a set of logical, systemic, and well-defined activities that provide the decision maker with a sound identification, measurement, quantification and evaluation of the risk associated with certain natural phenomena or man-made actions. The estimation of the potential adverse impacts of the waste disposal facilities on public health and the environment requires evaluation of the following:

- mass rate of release of both waterborne and airborne pollutants.
- areal extent of contamination, and persistence and transformation of the pollutants and their transformation products.
- concentrations and gradients of those pollutants that adversely impact air, water and land resources.
- number of people and especially sensitive populations that could be influenced by the release of pollutants from the site.
- total period of time over which pollutant release will occur.
- duration of exposure.
- synergistic and antagonistic impacts of other pollutant releases or adverse health conditions that might cause an exposed population to be more susceptible to pollutants derived from the site.
- characteristics of the site such as the depth of solid waste and degree of compaction.
- characteristics of the wastes accepted by the site owner/operator during the landfill's active life.
- size of the site as defined by the total amount of solid waste disposed of and the areal extent.

Although one of the objectives of scientific risk assessment is objectivity, it is still subjective due to the non-availability of specific data on the dose response relationship for the chemicals of concern and the number of assumptions and interpretations involved in the process. In the face of uncertainty, it is fit to have a simple quantification tool based on expert judgment to analyse the risk conditions. Saxena and Bhardwaj (2003) have reported such an approach to assess the hazard potential rating prior to developing an up-gradation plan for existing MSW dumpsite at

Panki landfill site, Kanpur, India. Kumar and Alappat (2003) have developed a Leachate Pollution Index which has many applications including ranking of landfill sites, resource allocation for landfill remediation, trend analyses, enforcement of standards, scientific research and public information. A risk based approach to solid waste management using a Landfill Location Criteria Calculator (LLCC), has been reported by Btenya et al (2005). LLCC allows communities to identify the risk factors and ultimately to minimize the cost of effective landfill management.

3. METHODOLOGY

The steps involved in the development of the risk based decision-making tool are:

- Selection of risk indicating attributes for evaluation of the dumpsites
- Apportionment of a total score of 1000 among the attributes based on their importance assigned by a panel of experts
- Analysing the sensitivity of the attribute based on a Sensitivity Index and
- Validating the approach to selected dumpsites by application of measured values of attributes.

Risk indicative attributes were selected based on the literature, data obtained through observation of activities and investigations in and around a few dumpsites, consultation with experts on the contribution of the attributes to pollution, health risks and social impacts. The selection of the attributes was done based on the inputs of an expert panel consisting of academics (45%), municipal officers (18%), regulators (23%) and consultants (14%). Questionnaires were sent to experts in solid waste management in Asia. This questionnaire contained a total of 75 selected parameters under three classes, namely, site specific criteria, characteristics related to waste at dumpsite and those related to quality of leachate from dumpsite. The panel members were requested to select the parameters to be considered for developing the tool and to allot relative importance in terms of significance numbers ranging from 1 to 10. The attributes were then grouped into defined categories and ranked following the Delphi approach (Dalkey, 1968 cited in Brown, 1970).

The top ranking 27 parameters with scores over 65% were short-listed and weightage of attributes (Wi) were assigned based on the pair wise comparison method (Canter, 1996) such that the total weightage was 1000. Each attribute was measured in terms of a sensitivity index (Si) on scale of 0 to 1 to facilitate computation of cumulative scores called Risk Index (RI) that can be used for classification of dumpsites for closure or rehabilitation. While "0" indicated no or very less potential hazard. "1" indicated the highest potential hazard. Allotment of sensitivity indices for the selected parameters was made following earlier studies (Saxena and Bhardwaj 2003; CPCB 2005; MSW 2000; MoEF 1989).

The RI of the site was calculated using the following formula

$$RI = \sum_{i=1}^{n} W_i S_i$$

where, W_i - weightage of the i^{th} variable ranging from 0 – 1000

S_i - sensitive index of the i^{th} variable ranging from 0-1

RI - Risk Index variable from 0 – 1000

The site with higher score indicated more risks to human health and warranted immediate remedial measures at the site. The priority then decreased with decrease in the total score for the dumpsites. The dumpsite with the least score indicated low sensitivity and insignificant environmental impacts.

A comparison of this risk index method with hazard potential method of Saxena and Bhardwaj (2003) was done for the Perungudi and Kodungaiyur dumpsites in Chennai.

4. RESULTS AND DISCUSSIONS

Table 1 summarizes the results of the studies that can be used for developing the decision making tool for prioritization of dumpsite rehabilitation. The top ranking options focused mostly on site specific issues with a total of 20 attributes assigned with a total weightage of 711. Four waste related attributes with a total weightage of 221 and three leachate related attributes with a total weightage of 68 were also included in the selected attributes. Hazardous content of the waste obtained the maximum weightage of 71 out of 1000. The least weightage (3 out of 1000) was assigned to the methane content in the ambient air at the dumpsite.

The results of the validation exercise of the tool done for the Perungudi (PDG) and Kodungaiyur (KDG) dumpsites in Chennai, India presented in Table 2 show that the sites scored a RI of 569 and 579, respectively. The hazard potential of the site can be evaluated based on the overall score as detailed in Table 3. The classification has been done in line with the criteria recommended by Ministry of Environment and Forests, Government of India, for classification of risk potential of abandoned hazardous waste dumps (MoEF, 1989). Suggestions for further action for each category are also presented. The findings indicate that PDG and KDG have moderate hazard potential and both need to be rehabilitated immediately.

The hazard potential obtained for PDG and KDG following the method of Saxena and Bhardwaj (2003) was 505 and 491, respectively. The Risk Index of 569 and 579 obtained presently for PDG and KDG differs significantly as compared to those obtained employing the methodology suggested by Saxena and Bhardwaj (2003) for developing hazard potential. The variations can be attributed to the fact that 50% of the criteria used presently are different from those used by Saxena and Bhardwaj (2003). Variations not withstanding, the present approach has added advantages. For instance, the high values of Risk Index are clear indication of the grevity of environmental risk presented by the dumpsite. Further, the approach is easier to carryout.

Development of IRBA decision making tool is an attempt to provide guidance to Government and other implementing authorities for quick decision making for prioritizing actions related to dumpsite rehabilitation. Detailed investigations and regulatory approval may be required as per the respective national or local legislations. Further work to refine the approach with inputs from more experts in the region and validation by application to different dumpsites in Asia is in progress.

Table 1. Attribute Weightage and Sensitivity

Sl. No.	**Attribute**	**Attribute Weightage**	**Sensitivity Index**			
			0.0 – 0.25	**0.25 – 0.5**	**0.5 – 0.75**	**0.75 – 1.0**
	I - Site specific criteria					
1.	Distance from nearest water supply source (m)	69	> 5000	2500 - 5000	1000 – 2500	< 1000
2.	Depth of filling of waste (m)	64	< 3	3 – 10	10 – 20	> 20

3.	Area of the dumpsite (Ha)	61	< 5	5 – 10	10 – 20	> 20
4.	Groundwater depth (m)	54	> 20	10 – 20	3 – 10	< 3
5.	Permeability of soil (1×10^{-6} cm/s)	54	< 0.1	1 – 0.1	1 – 10	> 10
6.	Groundwater quality	50	Not a concern	Potable	Potable if no alternative	Non-Potable
7.	Distance to critical habitats such as wetlands and reserved forest (km)	46	> 25	10 – 25	5 – 10	< 5
8.	Distance to the nearest airport (km)	46	> 20	10 – 20	5 – 10	< 5
9.	Distance from surface water body (m)	41	> 8000	1500 – 8000	500 – 1500	< 500
10.	Type of underlying soil (% clay)	41	> 50	30 – 50	15 – 30	0 – 15
11.	Life of the site for future use (years)	36	< 5	5 – 10	10 – 20	> 20
12.	Type of waste (MSW/HW)	30	100% MSW	75% MSW + 25% HW	50% MSW + 50% HW	> 50% HW
13.	Total quantity of waste at site (t)	30	$< 10^4$	$10^4 – 10^5$	$10^5 – 10^6$	$> 10^6$
14.	Quantity of wastes disposed (t/day)	24	< 250	250 – 500	500 – 1000	> 1000
15.	Distance to the nearest village in the predominant wind (m)	21	> 1000	600 – 1000	300 – 600	< 300
16.	Flood proness (flood period in years)	16	> 100	30 – 100	10 – 30	< 10
17.	Annual rainfall at site (cm/y)	11	< 25	25 – 125	125 – 250	> 250
18.	Distance from the city (km)	7	> 20	10 – 20	5 – 10	< 5
19.	Public acceptance	7	No Public concerns	Accepts Dump Rehabilitation	Accepts Dump Closure	Accepts Dump Closure and Remediation
20.	Ambient air quality - CH_4 (%)	3	< 0.01	0.05 – 0.01	0.05 – 0.1	> 0.1
	II – Related to characteristics of waste at dumpsite					
21.	Hazardous contents in waste (%)	71	< 10	10 – 20	20 – 30	> 30
22.	Biodegradable fraction of waste at site (%)	66	< 10	10 – 30	30 – 60	60 - 100
23.	Age of filling (years)	58	> 30	20 – 30	10 – 20	< 10
24.	Moisture of waste at site (%)	26	< 10	10 – 20	20 – 40	> 40
	III –Related to leachate quality					
25.	BOD of leachate (mg/L)	36	< 30	30 – 60	60 – 100	> 100
26.	COD of leachate (mg/L)	19	< 250	250 – 350	350 – 500	> 500
27.	TDS of leachate (mg/L)	13	< 2100	2100 – 3000	3000 – 4000	> 4000

Table 2. Risk Index Work Sheet for Perungudi and Kodungaiyur Dumpsites

Sl. No.	**Attributes**	**Attribute Weightage**	**Perungudi Dumping Ground (PDG)**			**Kodungaiyur Dumping Ground (KDG)**		
			Attribute measurement	Sensitivity Index	Score	Attribute measurement	Sensitivity Index	Score
	I – Site specific criteria							
1.	Distance from nearest water supply source (m)	69	< 1000	0.875	60.375	< 1000	0.750	51.750
2.	Depth of filling of waste (m)	64	3	0.250	16.000	3	0.250	16.000
3.	Area of the dumpsite (Ha)	61	20	0.750	45.750	55	1.000	61.000
4.	Groundwater depth (m)	54	2-10	0.900	48.600	4-6	0.900	48.600
5.	Permeability of soil ($1x10^{-6}$ cm/s)	54	3.2×10^{-7}	0.325	17.550	8×10^{-7}	0.450	24.300
6.	Groundwater quality	50	NP	0.875	43.750	NP	1.000	50.000
7.	Distance to critical habitats such as wetlands and reserved forest (km)	46	< 10	0.750	34.500	< 4	1.000	46.000
8.	Distance to the nearest airport (km)	46	10	0.500	23.000	50	0.125	5.750
9.	Distance from surface water body (m)	41	< 1000	0.625	25.625	3000	0.375	15.380
10.	Type of underlying soil (% clay)	41	> 50	0.100	4.100	> 50	0.100	4.100
11.	Life of the site for future use (years)	36	15	0.625	22.500	15	0.625	22.500
12.	Type of waste (MSW/HW)	30	MSW	0.100	3.000	MSW	0.100	3.000
13.	Total quantity of waste at site (t)	30	15×10^{6}	0.750	22.500	12×10^{6}	0.750	22.500
14.	Quantity of wastes disposed (t/day)	24	2200	1.000	24.000	1800	0.750	18.000
15.	Distance to the nearest village in the predominant wind (m)	21	< 1000	0.375	7.875	< 1000	0.375	7.880
16.	Flood proness (flood period in years)	16	> 100	0.100	1.600	> 100	0.100	1.600
17.	Annual rainfall at site (cm/y)	11	14.56	0.200	2.200	14.56	0.200	2.200
18.	Distance from the city (km)	7	10	0.500	3.500	10	0.500	3.500
19.	Public acceptance	7	Accepts dump rehabilitation	0.500	3.500	Accepts dump rehabilitation	0.500	3.500
20.	Ambient air quality - CH_4 (%)	3	< 0.01	0.100	0.300	< 0.01	0.100	0.300

	II – Related to Characteristics of Waste at Dumpsite							
21.	Hazardous contents in waste (%)	71	< 10	0.100	7.100	< 10	0.100	7.100
22.	Biodegradable fraction of waste at site (%)	66	40	0.583	38.478	40	0.583	38.478
23.	Age of filling (years)	58	18	0.775	44.950	18	0.775	44.950
24.	Moisture of waste at site (%)	26	35	0.681	17.706	24	0.500	13.000
	III – Related to Leachate Quality							
25.	BOD of leachate (mg/L)	36	12-86	0.500	18.000	< 300	1.000	36.000
26.	COD of leachate (mg/L)	19	200-1100	1.000	19.000	70-2000	1.000	19.000
27.	TDS of leachate (mg/L)	13	1000-7000	1.000	13.000	1000-8000	1.000	13.000
	Risk Index				**569**			**579**

Table 3. Criteria for Hazard Evaluation Based on the Hazard Potential Index

Sl. No	Overall Score	Hazard Evaluation	Recommended Action
1.	750-1000	Very High	Close the dump with no more land filling in the area. Take Remedial action to mitigate the impacts
2.	600 – 749	High	Close the dump with no more land filling in the area. Remediation is optional.
3.	450 – 599	Moderate	Immediate Rehabilitation of the dumpsite into Sustainable Landfill
4.	300 – 449	Low	Rehabilitate the dumpsite into Sustainable Landfill in a phased manner
5.	< 300	Very Low	Potential Site for future Landfill

ACKNOWLEDGEMENT

The authors wish to thank the Swedish International Developmental Co-operation Agency (SIDA) for financial support in carrying out the research and the permission and co-ordination of Corporation of Chennai during the study.

REFERENCES

Akolkar, A.B., Vidyarthi, A.K., and Sengupta, B., (2003), *Proc. Workshop on Sustainable Landfill Management*, Chennai, India, pp. 327 – 336.

Brown, R.M, Nina. I. Mc Clelland., Rolf, A.D., and Ronald, G.T. (1970) A water Quality Index – Do We Dare? *Water Sewage Works*, October 1970, pp. 339 – 343.

Buteyn, D. Simmons, L and Roberts, J. (2005), The Landfill Location Criteria Calculator. A Risk Based Approach to Solid Waste Management. *Proc. 20th International Conference on Solid Waste Technology and Management* – Philadelphia, April 3 – 6, pp. 403 – 409.

Canter L.W. (1996), Environmental Impact Assessment, Second Edition, *McGraw-Hill Inc.*, USA.

CPCB (2005), Environmental Impact Assessment for site selection for common hazardous waste management facility – http://envfor.mic.in/cpcb/hpcrexpert/vol.131.htm; Accessed on January 2005.

Cossu, R., Hogland, W. and Salerni, E. (1996). Landfill Mining in Europe and USA. ISWA Year Book, *International Solid Waste Association* (ed), pp 107-114.

Dalkey, N.C. DELPHI (1968), The Rand Corporation, cit. in Brown et al.

Hogland, K.H.W., Jagodzinski, K. and Meijer, J.E. (1995). Landfill Mining Tests in Sweden. Proceedings Sardinia 95, *Fifth International Landfill Symposium*, 2-6 October 1995, Cagliari, Italy.

Ishii, K., Furuichi, T, Tanikawa, N and Inaba, R. (2005). Proposal of Restoration and Reclamation System for Illegal Dumping and Uncontrolled Landfill Sites Based on Biotechnology. *Proc. 20th International Conference on Solid Waste Technology and Management* – Philadelphia, April 3 – 6, pp. 410-419.

Kurian Joseph, R. Nagendran , K. Palanivelu , K. Thanasekaran and C. Visvanathan (2004), *Dumpsite Rehabilitation and Landfill Mining* , CES, Anna University, Chennai-600 025, India

Kumar. D and Alappat, B.J. (2003), A technique to quantify landfill leachate pollution, Proc. Sardinia, *Ninth International Waste Management and Landfill Symposium*. Cagliari, Italty, 6 – 10 October 2003.

MSWMHR (2000), *Ministry of Environment and Forests*, Govt. of India.

MoEF (1989) " Guidelines for management and handling of hazardous wastes", *Ministry of Environment and Forests*, Government of India, New delhi.

Rushbrook, P. (2001). Guidance on Minimum Approaches for Improvements to Existing Municipal Waste Dumpsites, *WHO Regional Office for Europe*, Copenhagen, Denmark.

Saxena, A.K. and Bhardwaj, K.D. (2003) Environmental Assessment and up-gradation plan for existing municipal waste disposal site – A case study. *Proc. Workshop on Sustainable Landfill Management*, Chennai, India, pp. 287 – 301.