2nd International Conference on New Frontiers in Chemical, Energy and Environmental Engineering (INCEEE - 2019)
15-16 Feb, 2019, NIT Warangal, India

An Approach for Risk Index Assessment due to Direct Contact to the Municipal Solid Waste dumps

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ABSTRACT

Due to rapid urbanization and growth in the population in India, the generation rate of municipal solid waste is increased and it leads to the problem of waste management. Waste is being disposed in open which leads to the various environmental problems. To overcome these problems, the dumpsites need to be close and remedial measure to be taken according to their contamination potential. Various methods are being used to assess the risk from these dumpsites. Hazard rating systems are most common because these are easy to use and require less data than other approaches.

This method assesses the risk by Direct Contact route and is based on Source – Pathway – Receptor linkage methodology. Basic parameters like area, height and composition of waste is added to the existing system HDM (Hazard Decision Model). This system is applied to the seven artificial dumpsites with varying characteristics. Sensitivity analysis of new system is performed to check the sensitivity of each parameter on the system. Clustering analysis of new and existing systems are compared direct contact route like ERP-HRS (Environmental Repair Problem Hazard Ranking System) and HDM. The direct contact risk index assessment is done for two dumpsites of Prayagraj, India. New system shows better and justified results and this system can be used to assess the direct contact risk from the dumpsites.

Keywords: Direct Contact, Risk Assessment, Open Dumping, Municipal Solid Waste, Source – Pathway – Receptor.

1 INTRODUCTION

As a result of rapid urbanization and rapid population growth in India lead to generation of huge quantity of waste and environmental degradation. Various studies have confirmed that open dumping of waste leads to various problems such as groundwater contamination, surface water contamination, air pollution and various disease vectors are grown due to it [2, 4, 6, 9, 15-17]. Due to financial aspects India is not able to rehabilitate all the dumpsites. There is need to determine risk due to the dumpsite. Various hazard rating systems are available and are widely used by various countries. Many of them are not applicable for Indian problems because conditions in India differs from developed countries.

In this study, various factors affecting the direct contact are being identified based on previous literature and also there interrelationship are find out. Some factors from existing systems were replaced with the new factors and are properly arranged. The improved system has been compared with the existing systems by applying them to the set of waste dumpsites of varying characteristics. Sensitivity analysis and clustering analysis were performed for both new and existing system. Lastly, direct contact risk index assessment were done for Phaphamau and Bakshi Band dumpsites of Prayagraj, India and also compared with the ratings from HDM and ERP-HRS.

2 EXISTING SYSTEMS FOR WASTE DUMPS

Various systems like ERP-HRS, DRASTIC, RASCL, JENV, RSS, GW-HARAS, SW-HARAS, OD-HARAS, HDM, WARM etc. exist to assess various environmental hazards from the waste dump sites. Systems formulated in developed countries do not work well in India because of large size of the dumpsites. So, system from the developed countries needs to be modified before using it in India. Table 1 gives an overview of existing assessment tools and their hazard routes.

Table 1 Existing systems for risk assessment and their routes considered

System Name	Groundwater	Surface water	Air	Direct contact	Explosion	Reference
ERP-HRS	√	√	√	√	√	[5]
DRASTIC	√					[1]
JENV	Combined Score					[7]
RSS	√	√		√		[10]
GW-HARAS	√					[14]
HDM	√			√	√	[11]
OD-HARAS			√			[8]
SW-HARAS		√				[3]
WARM	√	√	√			[13]

Source – Pathway – Receptor methodology is very common and is used in most of these systems. These systems are based upon various routes for contamination transport like groundwater, surface water, soil, air, and direct contact etc. These systems have various parameters and different scoring algorithms.

3 FRAMEWORK FOR NEW SYSTEM

The framework of the new system is derived from already developed system by [3, 11]. This system is based on Source – Pathway – Receptor concept (Fig. 1). In this study, Source means Dumpsite and parameters associated with dumpsite referred as Source parameters. Mainly it covers the quantity and quality of waste. Pathway refers to the parameters associated with migration of contamination from source to the receptor. Receptor means living being and surrounding environment affected from dumpsite.

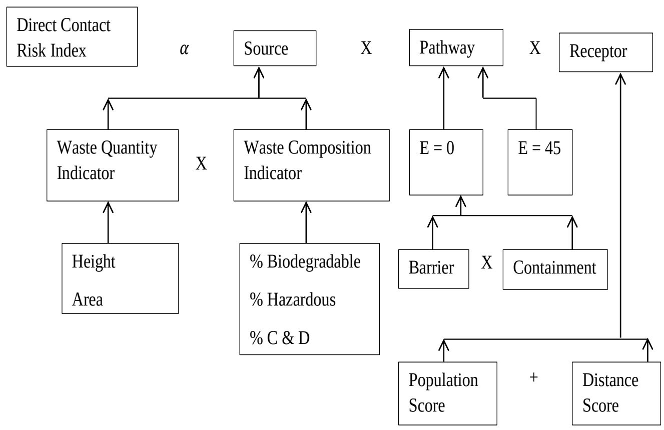

Figure 1: Conceptual diagram for framework of direct contact risk index

For risk evaluation each of the three components is assessed on a scale based on various parameters. In the proposed system, Risk index due to direct contact due to dumpsite is given by

$$RI_{DC} = \frac{RI_S * RI_P * RI_R}{SF} * 1000 \quad (1)$$

Where,
RI_S is the source risk index, RI_P is the pathway risk index, RI_R is the receptor risk index and SF is the scaling factor.

4 GUIDING PRINCIPALS

The evaluation of components is based on some observations:

i. The larger quantity of waste will have greater direct contact; so greater direct contact risk index.
ii. The greater percentage of biodegradable waste as compared to construction and demolition waste will have more direct contact risk.
iii. In case of evidence where the contact to the waste material at dumpsite resulted to the illness, injury or death to any animal or human will be considered more hazardous.
iv. In case of no such evidence (explained in iii) direct contact risk will depend on barrier and containment.
v. If dumpsite is accessible to the human or animal easily then the direct contact risk will be higher.
vi. If bottom of dumpsite is in direct contact with the soil, pond or creek etc. then direct contact risk will be more.
vii. Presence of more population near the dumpsite will have higher direct contact risk.
viii. If dumpsite is near the sensitive environment then it will have more direct contact impact.

5 METHODOLOGY

5.1 Direct Contact Risk Index Assessment

The system consists of source, pathway and receptor. The source is assumed to depend mainly on waste area, waste height and waste composition. The pathway consists of evidence, barrier and containment. The receptors are mainly dependent on population near the dumpsite and distance from the sensitive environment.

5.1.1 Source risk index

The source risk index is given by:

$$RI_s = W_{qi} * W_{ci} \quad (2)$$

Where,
W_{qi}= waste quantity indicator and
W_{ci}= waste composition indicator have been defined in (14).
The waste quantity indicator is a measure of total waste quantity in a landfill in comparison to other landfill and is given by:

$$W_{qi} = \sqrt{\frac{W_q}{3}} \quad (3)$$

Where,
W_q= waste quantity in tons.
The density of wastes at the landfill is assumed to be 0.80 tons/ m^3 [12]. The maximum value of W_{qi} is limited to 1000.
The waste composition indicator is relative measure of toxicity of waste. For mixed waste W_{ci} is given as

$$W_{ci} = \frac{25H + 5B + C}{5} \quad (4)$$

Where,
H = Hazardous Fraction (%),
B = Biodegradable fraction (%),
C = C&D waste fraction (%), and $H+B+C \leq 100$.
The value of W_{ci} should be less than 100.

5.1.2 Pathway risk index

The pathway risk index is calculated as

$$RI_p = E, \text{ if } E = 45 \quad (5)$$

$$RI_p = B_i * C_i \text{ if } E = 0 \quad (6)$$

Where, E = Evidence where the direct contact to the dumpsite causes illness, death, or injury to the human or animal. The value of E is taken as 45 otherwise 0.
B_i= Barrier, and
C_i = Containment.
B_i= Barrier score is explained in Table 2 and are based on ERP-HRS.
Containment (C_i) indicates if the waste dump is in direct contact with the ground surface, shallow pond or creek than i=this value is assigned as 15 otherwise 0. Containment, C_i, in case of waste dump sites in Indian condition is 15 as each site has the direct contact with the surface as there is no liner system for dumpsites.

Table 2 Barrier score based on site condition

Barrier	**Barrier Level**	**Score, B_i**
A 24 – hour surveillance system which continuously monitors and control entry onto the facility. OR An Artificial or Natural barrier which surrounds the facility and control entry all the time.	Level 4	0
Security guard, but no barrier	Level 3	1
A barrier, but no other way to control entry	Level 2	2
Barriers do not completely surround the facility	Level 1	3

5.1.3 Receptor risk index

Receptor risk index is based on HDM [11] and it is given by:

$$RI_R = D_{SN} + N_{Pop} \tag{7}$$

Where,

D_{SN} = Distance score which indicates score according to the distance to the Sensitive Environment, and

N_{Pop}= Population score which indicates population at risk of Direct Contact.

$$D_{SN} = 21.9 - (Distance(km) * 5.4878) \tag{8}$$

For Distances ≥ 3.25 km, D_{SN} value is taken to be 0 and for distances ≤ 0.4 km, the value of D_{SN} is taken to be 20.

$$N_{Pop} = 3.83 * population^{0.1742} \tag{9}$$

N_{Pop} indicates score for population at risk of direct contact, living within 1.6 km radial distance of the dumpsite. For population ≥ 13000, N_{Pop} is taken to be 20.

5.1.4 Overall direct contact risk index

The direct contact risk index can be calculated by using equation (1):

$$RI_{DC} = \frac{RI_S * RI_P * RI_R}{SF} * 1000$$

Where,

RI_{DC} is the direct contact risk index and SF is the scaling factor.

The scaling factor is equal to the product of source, pathway, and receptor risk index of waste dumpsite having its parameters at worst values. The maximum value of risk index of a site is restricted to the 1000. The best and worst values are given in Table 3.

Table 3 Best and worst value of site parameters for new system for direct contact

S. No.	**Waste Site Parameters**	**Best Values**	**Worst Values**
1.	Waste site area	≤ 5	≥ 25
2.	Waste site height/depth	≤ 5	≥ 15
3.	Biodegradable Fraction (%)	0	≥ 75
4.	Hazardous Fraction (%)	0	≥ 75
5.	C & D (%)	100	0
6.	Evidence, E	No	Yes
7.	Barrier, B_i	Level 4	Level 1
8.	Containment, C_i	Yes	No
9.	Distance to the sensitive environment (km)	≥ 3.25	≤ 0.4
10	Population at risk of Direct Contact	0	≥ 13000

6 VALIDATION OF THE PROPOSED SYSTEM

The proposed system is validated by three criteria: ranges of scores, clustering analysis and sensitivity analysis.

The performance of risk index can be measured in terms of spread of values of score of waste sites of continuously varying properties. Clustering analysis is done to measure uniformity in the spread of score across 0 to 1000. Sensitivity analysis is done to measure the response of the system to the variation in the values of individual parameters.

6.1 Application to Sites having Varying Characteristics

The new system was applied to the seven artificial dumpsites having varying characteristics from W1 to W7 with increasing direct contact risk index. The best and worst values of parameters are selected from the various literatures. The site characteristics for the waste dumps are given in Table 4. The score calculated from new system is in the range of 0-1000 (Table 5). The scores from new system is compared with existing (Table 6, Fig. 2).

The scores obtained from the new system is checked for clustering index and also compared with the clustering index from the HDM and ERP-HRS and results are shown in Table 6. Clustering index is the indication for the spread of results to the full scale; lower the value indicates better spread. Clustering index is calculated as given in [3].

Table 4 Site characteristics of the waste dump sites with continuously varying characteristic

Waste Parameters	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**
Waste site area (ha)	5	10	15	15	20	25	30
Waste site height/depth (m)	5	10	12.5	15	15	15	20
Waste Toxicity	L-0	L-1	L-1	L-2	L-2	L-3	L-4
Biodegradable Fraction (%)	40	50	60	65	65	70	75
Hazardous Fraction (%)	1	2	3	3	4	4	5
C & D (%)	30	25	20	15	10	5	0
Evidence, E	No	No	No	No	No	No	Yes
Barrier, B_i	L-4	L-3	L-3	L-2	L-2	L-1	L-1
Containment, C_i	No	No	No	No	No	No	No
Distance to the sensitive environment (km)	3.25	3.0	2.5	2.0	1.5	1.0	0.4
Population at risk of Direct Contact	500	3000	5000	7000	8000	10000	13000

Table 5 Direct contact risk index for dumpsites with continuously varying characteristics

Risk Index	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**
Source Risk Index	13168	33566	55861	64292	77815	91000	100000
Pathway Risk Index	0	15	15	30	30	45	45
Receptor Risk Index	11	21	25	29	32	35	40
Overall Risk Index	0	58	117	309	415	807	1000

Table 6 Direct contact risk index for dumpsite with new and existing systems

Score	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**Clustering Index**
New System	0	58	117	309	415	807	1000	0.28
HDM	0	58	70	320	355	887	1000	0.45
ERP – HRS	0	56	56	278	333	750	1000	0.39

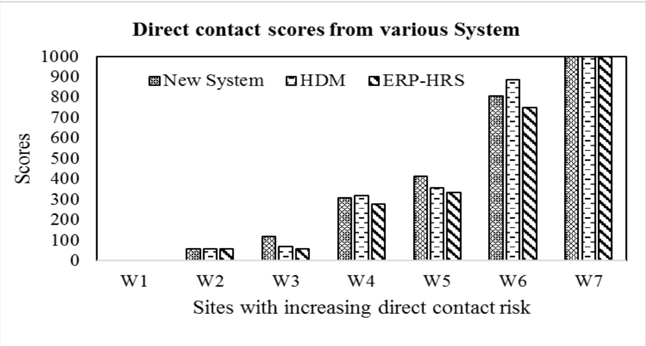

Figure 2: Direct contact risk index from new and existing systems

6.2 Sensitivity Analysis for Direct Contact Risk Index

Sensitivity analysis of improved system was carried out to observe the sensitivity of the system to changes in values of various parameters. To perform sensitivity analysis, a site having values of all parameters at their mid value was assumed as base case (Table 7). The results of sensitivity analysis have been given in Table 8.

Table 7 Parameters at base case for sensitivity analysis for direct contact

S. No.	**Site Parameters**	**Parameter value**
1	Waste site area (ha)	15
2	Waste site height/depth (m)	10
3	Waste Toxicity	Level 2
4	Biodegradable Fraction (%)	60
5	Hazardous Fraction (%)	3
6	C & D (%)	10
7	Evidence, E	No
8	Barrier, B_i	Level 2
9	Containment, C_i	No
10	Distance to the sensitive environment (km)	2.0
11	Population at risk of Direct Contact	7000

Table 8 Results from sensitivity analysis of new system for direct contact

Base case scenario		Best and worst values for the parameters (change as % of full range)	Resultant Score (New System)		Total Change (%)
Site parameters	Parameter value		Score	% Change	
Waste site area (ha)	15	5 (-67%)	135	- 42.3	71.4
		25 (67%)	302	29.1	
Waste site height/depth (m)	10	5 (-50%)	165	- 29.5	52.1
		15 (50%)	287	22.6	
Biodegradable Fraction (%)	60	30 (-50%)	143	-38.9	76.9
		90 (50%)	323	38.0	
Barrier, B_i	Level 2	Level 4	0	-100	150
		Level 1	351	50	
Distance to the sensitive environment (km)	2.0	1.0 (-50%)	278	18.8	38
		3.0 (50%)	189	-19.2	
Population at risk of Direct Contact	7000	3500	217	- 7.3	12
		10500	245	4.7	

*Score for the base case was 234.

From the sensitivity analysis, it can be seen that system is most sensitive to the pathway factors. The total change in the score is about 150 % when pathway scenario changes from best to the worst. Waste site area, height, barrier and Biodegradable fraction shows high sensitivity. Distance to the sensitive environment and population at risk of direct contact shows minimum changes.

7 SYSTEM APPLICATION

The new system was applied to the two dumpsites (Phaphamau and Bakshi Band) of Prayagraj. These sites are old and do not receive waste at present and do not have any liner or cover system. Sites are present in low lying area near Ganga River in Prayagraj. Site parameters are given in Table 9. To obtain data regarding dumpsites, office of Prayagraj Municipal Corporation was contacted. Some of the data was obtained by the site visit to the dumpsite and parameters like waste area and distance to the river etc. were taken with the help of bhuvan portal.

The score obtained for Phaphamau and Bakshi Band from new system is given in Table 10. The direct contact risk index is higher for Bakshi Band than Phaphamau due to greater size of Bakshi Band site.

Table 9 Site Characteristics of MSW dumps of Prayagraj

Parameters	Phaphamau	Bakshi Band
Waste site area (ha)	0.6	5.5
Waste site height/depth (m)	8.5	10
Biodegradable Fraction (%)	64	64
Hazardous Fraction (%)	1	1
C & D (%)	20	20
Evidence, E	No	No
Barrier, B_i	Level 1	Level 1
Containment, C_i	No	No
Distance to the sensitive environment (km)	0	0
Population at risk of Direct Contact	≥ 13000	≥ 13000

Table 10 Direct contact risk index of dumpsites from new system

Site	Phaphamau	Bakshi Band
Source Risk Index	8259	27957
Pathway Risk Index	45	45
Receptor Risk Index	20	20
Overall Groundwater Risk Index	41	139

8 CONCLUSIONS

The following conclusions can be drawn from the study:

- The proposed system evaluates the risk from the dumpsite due to the direct contact route. The study includes various parameters waste area, waste height, waste composition, barrier, containment, evidence, population at risk to direct contact and distance to the sensitive environment.
- The new system shows lower value of clustering index than the existing systems, the system with no clustering means the scores are evenly distributed over full range of scale.
- From the sensitivity analysis of new system, the parameter Barrier shows the maximum sensitivity and the population at the risk of direct contact shows the minimum sensitivity.
- When new system is applied to the municipal waste dumpsites of varying characteristics, the new system gives the score in the range of 0 – 1000.
- Waste dump sites of Prayagraj shows lower value of direct contact risk index due to the smaller size of the dumpsite.
- Direct contact risk index can be further minimized by providing with the higher level of barrier or restricting the dumpsite area to the public by some boundary.

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