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# Hydrogeological Environmental Assessment of Sanitary Landfill Project at Jammu City, India

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The environmental impact assessment process has been envisaged as an integral part of development planning aimed towards minimizing environmental degradation. This study is a preliminary assessment of the possible environmental impact of a proposed landfill facility for the city of Jammu in India. The objectives of this preliminary assessment are: to compile an environmental inventory of the project area, to predict the possible impact on groundwater quality; and to prepare an environmental management plan of the project site. The vulnerability of ground water to contamination in the study area was quantified by using the DRASTIC model. The calculated DRASTIC index number indicates a high pollution potential for the study area.

**Keywords:** landfill, environmental impact, aquifer, lechates, DRASTIC.

The safe and reliable long-term disposal of solid waste residues is an important component of integrated waste management. Historically, landfills have been the most common, environmentally and economically acceptable method of disposal of solid waste. Even with the implementation of waste reduction, recycling, and transformation technologies, disposal of solid waste in landfills remains a significant component of an integrated waste management strategy (Tchobanoglous, Theisen & Vigil, 1993).

Environmental impact assessment (EIA) can be defined as the systematic identification and evaluation of the potential impacts of proposed projects, plans, programs, or legislative actions relative to the physical, chemical, biological, cultural, and socio-economic components of the total environment. The prime purpose of the EIA process is to encourage the consideration of the environment in planning and decision-making to ultimately arrive at actions that are more compatible with the environment (Canter, 1996).

In India the environmental impact assessment exercises in the case of landfill projects are still at a development stage. Environmental legislation

pertaining to the submission of an environmental impact assessment report for landfills was enacted two years ago. To date, about 50 sanitary landfill projects have been conceived, designed, and completed in India. But consideration of the environmental parameters in designing and developing these projects has been neglected. According to legislation on municipal solid waste-formulated and enacted by the Union Ministry of Environment and Forest as empowered under the Environment Protection Act of 1986-the submission of an environmental impact assessment prior to the designing and development of any landfill facility in the country has been made mandatory (*Government of India, Management & Handling Rules, 2000*). Any municipal authority or designated agency engaged in the management of municipal solid waste anywhere in the country must perform an environmental impact assessment of the proposed site for a sanitary landfill operation. Landfill projects must comply with the standards for air, water (ground and surface), pollution, and other environmental norms (Bhardwaj & Singh, 1997).

### **Objective and Importance of Study**

The development of a sanitary landfill facility proposed by the local municipal corporation of the city of Jammu is justifiable as ensuring the establishment of a sound solid waste management system. Jammu has experienced massive urbanization in recent years and the present system of solid waste management has failed to accommodate the quantity of solid waste that is presently being generated in the city. A preliminary environmental impact assessment study for the proposed project has the following objectives:

1. To compile an environmental inventory of the project area. This includes the following details:
  - a. Hydrogeological settings
  - b. Geographical and meteorological details
  - c. Land use pattern of the study area
  - d. Ground water quality of the study area
  - e. Demographic details
2. To predict the possible impact on groundwater quality
3. To prepare an environmental management plan of the project site

### **Environmental Inventory of the Project Area**

The study area of Jammu district, the winter capital of Jammu and Kashmir state, falls between 32°35'N to 32°55'N and 74°45'E to 75°00'E, covering an area of 870 square kilometres.

### *Physiography, Relief and Drainage*

The study area is comprised of flat land and small hills. The main township is adjacent to lower Shivaliks, which are comprised of lower Himalayan Mountains. The topography is mostly undulating hills. The altitude in the area varies considerably from one location to another, the average height being 500 meters. The main drainage systems in the area are the Chenab, Tawi, Basantar and Ujh rivers. The Chenab is perennial and snow fed. The rest of the rivers are seasonal rivulets known as *Khads* that traverse the area (*Groundwater yearbook, 1997*).

### *Climate and Rainfall*

The climate of the area is subtropical characterized by three distinct seasons: winter, summer, and Monsoon. May and June are the hottest months while December and January are the coldest. The annual average ambient temperature varies from 2°C to 40°C.

### *Geology*

The geology of the area consists of Shivaliks region systems and is mainly composed of sandstone and red transported quartzite. The lower accessible area, including the foothill plains, consists of alluvial deposits left by the seasonal rivulets, which carry away rainy water during Monsoon season. The parent material is mainly composed of alluvium and co-alluvium on the foothill plains. Accordingly, the study area was divided into recent, sub-recent, and Shivaliks groups (*Groundwater yearbook, 1997*).

### *Soils*

The soils of Jammu show complete heterogeneity. The soils of the foothill and adjoining area are composed of boulders and gravel with ferruginous clay. These types of soils are spread over in the study area and are generally loams, but poor in clay content. Soils on the foothills and V-shaped small valleys have been found to be deep with a medium to heavy texture (*Groundwater book, 1997*).

### *Land Use Pattern*

Table 1 shows that in 1995 around 35% of the region is under cultivation, 37% is forested, 29% is watershed, 0.25% is urban, and 2% of the area is snow cover (Bhardwaj & Singh, 1997).

Table 1

*Land Use Pattern Change in Jammu*

Land Use	1990		1995	
	Area (sq km)	Area (%)	Area (sq km)	Area (%)
Residential	45.66	5.29	78.98	9.04
Industrial	6.20	0.71	12.47	1.43
Construction	9.80	1.13	4.08	0.47
Institutional	5.10	0.59	5.29	0.61
Rural	4.60	0.53	8.73	1.00
Commercial	-	-	0.20	0.02
Stadium	0.15	0.02	0.09	0.01
Airport	1.00	0.12	1.00	0.12
Railway	0.59	0.07	0.18	0.02
Bus terminal	0.32	0.04	0.34	0.04
Agriculture	330.08	37.80	306.14	35.05
Agricultural fallow	1.97	0.23	3.06	0.35
Orchards	0.64	0.07	0.18	0.02
Dense forest	77.40	8.87	36.22	4.15
Bushes	257.88	29.53	296.54	33.96
Rivers	37.94	4.34	33.31	3.81
Khads	58.24	6.67	54.88	6.28
Waterlogged	2.94	0.34	2.18	0.25
Gullies and ravines	0.85	0.10	-	-
Defence lands	25.63	2.93	26.10	2.99
Total	873.33	100.00	873.33	100.00

*Infiltration Characteristics*

The soil infiltration rates vary under different conditions, land uses, and soil types in different hydro-climatic environments. Some recently conducted studies show that initial infiltration rates vary from 0.03 to 2.4 cm/hr for bare ground, 1.2 to 3.0 for agricultural land, 0.3 to 6.3 for grassland, and 0.6 to 1.2 for forestland respectively (Onkar & Patwary, 1997).

*Demographic Details*

The pressure on the available resources exerted by the population has an affect on the area. More than 1.2 million people live in Jammu, which comprises about 76% of the total area population; the rest of the population

lives in villages. The population density is about 280 persons per square kilometre since the area is very easily accessible and is served by all modern means of transportation while the environmental conditions are conducive to settlement (*Groundwater yearbook, 1997*).

### Existing Groundwater Quality

The average groundwater level in the Jammu region is at a depth of 18.8 metres below ground level. The average monitoring results of groundwater quality studies show that the general pH of the water varies from 6.5 to 8.5 showing its suitability for drinking purpose (Nagar, 1996). The electrical conductivity values have been shown to exceed the limit of 750-2250 micro-mhos/cm. Total dissolved solids have been found to be of 15800 mg/l. Calcium has been found to be within the acceptable limits, which is 250 ppm. The measured nitrate concentration exceeds the limit of 45 mg/l. The reason for these values can be attributed to agriculture runoffs, which result in transportation of nutrients from agricultural fields to water bodies. The fluoride was also found to exist in acceptable limits, which are 1.5 ppm as shown in Table 2 (*Groundwater yearbook, 1997*).

Table 2

#### *Groundwater Quality in Jammu District*

Parameter	August 1995			December 1995			March 1996		
	Min.	Max.	Ave.	Min.	Max	Ave.	Min.	Max.	Ave.
pH	6.34	8.55	7.13	6.73	8.12	7.32	6.66	8	7.2
EC (mhos/cm)	400	1435	796	455	4481	1224	467	3159	1087
TDS (mg/l)	258	911	493	295	2875	801	290	2035	699
HCO <sub>3</sub> (mg/l)	92	334	209	152	808	367	136	672	329
Hardness (mg/l)	151	740	325	169	916	415	152	980	331
Cl (mg/l)	4	340	66	0	520	82	0	448	70
SO <sub>4</sub> (mg/l)	5	384	48	20	590	91	8	476	76
PO <sub>4</sub> (mg/l)	0.06	2.15	0.3	-	-	0.21	0	2.64	0.24
NO <sub>3</sub> (mg/l)	-	-	-	-	-	-	-	-	-
Ca (mg/l)	38.5	296	85	37	279	116	5	359	84
Mg (mg/l)	0	87	22	0	102	29	0	79	29
K (mg/l)	0.39	151	29	0.08	282	34	1.1	400	43
Na (mg/l)	4	110	23	3	350	65	6	275	47

## **Assessment of Hydrological Environment**

### *Assessment of Aquifer Vulnerability using the DRASTIC Method*

The prepared landfill project is supposed to cause some micro-scale impacts, which would be of significant nature on the soil or groundwater within the project area. These significant groundwater impacts are evaluated here using an aquifer vulnerability mapping technique called DRASTIC (Aller, et al., 1987). DRASTIC is a methodology for identifying vulnerability to groundwater pollution. It uses seven parameters, which are a combination of geologic, hydrologic, geomorphologic, and meteorological factors, to relate an aquifer to the sources of its water and the constituents within that water. The parameters (**D**epth of water, annual **R**echarge, **A**quifer media, **S**oil media, **T**opography, vadose zone **I**mpact, and hydraulic **C**onductivity) are weighted according to their relative importance in determining the ability of a pollutant to reach an aquifer. The parameters are used to produce DRASTIC index numbers from which maps can be constructed.

The methodology was developed around a set of basic assumptions concerning a generic contaminant. They are:

1. Material introduced at the land surface as a soluble solid or liquid travels to the aquifer with recharge waters derived from precipitation.
2. The mobility of the contaminant is assumed to be equal to that of the groundwater.
3. Attenuation processes are assumed to go on in the soil, vadose zone and aquifer. DRASTIC was not specifically designed to deal with pollutants introduced in the shallow or deep subsurface, such as leaking underground storage tanks or deep mine wastes.

Ratings for each parameter are assigned depending on its contamination potential. Ratings vary from 1 to 10, with higher values describing greater pollution potential. These parameter ratings are used for all evaluations, however, each parameter is also weighted to account for differences between general land use and agricultural use. Weights range from 1 to 5, with higher weights representing greater pollution potential.

This technique is based upon the seven parameters, or factors, of the DRASTIC rating scheme coupled with a relative importance weight resulting in a rating for each factor. The factors are:

- D = Depth of groundwater
- R = Recharge rate (net)

- A = Aquifer media
- S = Soil media
- T = Topography (slope)
- I = Impact of vadose zone
- C = Transmissivity of aquifer (Conductivity)

Determination of the DRASTIC index number (pollution potential) for a given area involves multiplying each factor rating by its weight and adding together the resulting values. Higher sum values represent a greater potential for pollution or a greater vulnerability of the aquifer to contamination. For a particular area being evaluated, each factor is rated in a scale from 1 to 10 indicating the relative pollution potential of that factor for that area. Once each factor has been assigned a rating it is weighted. Weight values, from 1 to 5, express the relative importance of the factors with respect to each other. Finally the total impact factor score, the DRASTIC index number, can be calculated:

$$\text{Pollution potential} = D_r D_w + R_r R_w + A_r A_w + S_r S_w + T_r T_w + I_r I_w + C_r C_w$$

where

- r = Rating for area being evaluated (1-10)
- w = Importance weight for the factor (1-5)

Factor ratings are derived from data on each factor while importance weights are found in generic DRASTIC tables that list weights for factors having greater applicability (Aller, et al., 1987). The values of the factors for this study area were calculated from data from the southwestern Himalayan regional centre of the Indian Institute of Hydrology, Roorkee, India. The data of the various parameters of the study area are as follows:

Depth of groundwater	=	32.80 feet
Rate of net recharging	=	9 in/hr
Aquifer media	=	sandstone with pebbles
Soil media	=	sandy loam
Topography	=	5%
Impact of vadose zone	=	sand and gravel
Transmissivity of aquifer	=	1729 pd/ft

This information was calculated into specific values for each factor:

Depth of groundwater	=	5
Net recharge rate	=	8
Aquifer media	=	7.5



Soil media	=	6
Topography	=	9
Impact of vadose zone	=	7.5
Transmissivity of aquifer	=	8

These rating values are multiplied by their importance weight then added together to arrive at the DRASTIC index number:

$$\begin{aligned}
 \text{Pollution potential} &= \text{DrDw} + \text{RrRw} + \text{ArAw} + \text{SrSw} + \text{TrTw} + \text{IrIw} \\
 &+ \text{CrCw} \\
 &= 5 \times 5 + 8 \times 4 + 7.5 \times 3 + 6 \times 2 + 9 \times 1 \\
 &+ 7.5 \times 5 + 8 \times 3 \\
 \text{DRASTIC index number} &= 162
 \end{aligned}$$

The DRASTIC index number (pollution potential) is high, thus showing the vulnerability of the aquifer to contamination from the proposed landfill project.

### **Environmental Management Plan for the Project**

The environmental management plan for the landfill facility may primarily address the groundwater contamination and leachate management due to the terrestrial nature of environmental degradation caused by the project. The prevention of groundwater contamination would require the use of geosynthetic clay liners or membranes for the landfill. The contamination probability index calculated by the DRASTIC model was included in the remedial plan for the project. The high saturation of groundwater and the presence of alluvial soil media are the prime reasons that the project poses a contamination threat to the groundwater. Utilizing the liner technology of geosynthetic clay materials can mitigate this threat. It was decided to put in a drainage system in order to provide swift and smooth removal of water from rainstorms. The geosynthetic clay liner is provided in sandwiched layers of cement and other stabilization material. The groundwater monitoring will be done on a permanent basis in order to report any contamination caused by excessive leaching of heavy metals or other chemicals. Besides that leachate and landfill gas monitoring system, management of leachate and minimization of soil erosion may include some aspects of environmental management of the landfill project.

### **Conclusion**

The present environmental impact assessment of the landfill has been carried out to prepare a database of the impacts that could result from the project. In the present study, the environmental impacts that may occur are

analysed with particular emphasis on groundwater contamination. This study has been able to identify the critical deleterious environmental degradation that could occur from the project. The database prepared for the environmental inventory of the project may be useful for other studies in the area regarding the landfill management plan and its implementation during the later stages of the project.

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