SOLID WASTE MANAGEMENT — THE NEED FOR DEVELOPING DESIGN GUIDELINES

G.V. Ramana and G. Venkatappa Rao

Department of Civil Engineering, Indian Institute of Technology, Hauz Khas, New Delhi-110 016, India

ABSTRACT

In India, the need for containing municipal as well as hazardous waste is being increasingly felt There is a need to develop a rational and environmentally safe design and construction guidelines to manage the solid waste in our country The paper reviews the practices in some developed countries, particularly Unites States and suggests the need for guidelines for India and other developing countries

INTRODUCTION

India is experiencing an economic boom resulting from the recent economic liberalization policies In general booming economy results in higher volumes of generated waste and a greater use of industrial chemicals Protection of environment is an important need to be met in the pursuance of activities of economic and social progress India's outdated methods of dumping the waste on some hitherto unused land and/or burning the wastes (particularly hospital waste) without bothering about the subsequent environmental and health concerns need to be modified

Recent incidents in Surat, Delhi and the information coming out of Shimla and other hill towns as well, increased the public awareness of this environmental issue Several such cases have been already reported in our country and have become a concern for the municipalities, the respective state pollution control boards, Central Pollution Control Board (CPCB) as well as the Ministry of Environment and Forest (MEF) of Government of India

A waste landfill is an engineered structure with high risk potential because of the toxic and hazardous constituents of different types of waste. The structural elements of the landfill are designed with the goal to avoid unallowable emissions to air, soil or ground water (Jessberger 1994a) Beginning with clay layers about three decades ago, several kinds of lining systems to contain municipal solid waste (MSW) and hazardous solid waste (HSW) have been developed around the world These design guidelines are being continuously updated by organizations like the Environmental Protection Agency (EPA), USA and similar organizations in Europe Considerable experience has been gained on this issue.

In developing countries, there is a dire necessity to develop landfills to protect the environment In the absence of well engineered and natural barriers, release of leachate from waste containment systems may contaminate ground surface and ultimately infiltrate into sub-surface waters The absence of established guidelines, appropriate for the land use and climate and the economic status of the people makes the task quite involved It is necessary to study the experience of the rest of the world and develop preliminary guidelines for adoption in our country, atleast to begin with. These may be changes subsequently with passage of time and the experience gained.

Though clay liners (CCL's) are a good beginning and could possibly be adopted in rural areas or may be small townships, landfill construction and management involves several aspects to be dealt with and the design is more crucial than, say, building a dam. This is primarily because the landfill structures deal with millions of tons of waste collected over maybe 2-3 decades whose composition is not well established (unlike soils or concrete) and whose properties continue to change with time and environment.

The development of better waste disposal practices includes the use of geosynthetics in addition to CCL's as a part of barrier system in a landfill. Additionally, the quantity of surface water and ground water being contaminated at waste site can be reduced significantly by developing and implementing a landfill operation plan. Well engineered landfills using geosynthetics offer the best hope to contain leachate generated at waste disposal sites. The use of geosynthetic technology, however, has never been as simple as laying a geomembrane on the ground (Mackey 1996).

In the following sections, the role of geosynthetics in landfill construction is explained in detail with figures. The guidelines and philosophy of environmental regulations concerning solid waste management in different countries is presented. EPA regulations of United States concerning the use of geosynthetics in landfills is illustrated with figures. Finally, some initial guidelines for adoption in India and other developing countries are proposed regarding the use of geosynthetics.

LINED LANDFILLS AND GEOSYNTHETICS

In the solid waste management front (both MSW and HSW) in developed countries, geosynthetics are considered as the most important component of a landfill. Although clay or admixed liners minimize the leachate flow rates, they can not prevent leachate flow; once the leachate is absorbed in the clay, it is only a matter of time before it will migrate through the barrier. In developed countries, low permeability synthetic barriers, referred to as flexible membrane liners (FMLs) or geomembranes are being used extensively to contain the leachate.

Almost all types of geosynthetics could be of use in landfills. Figure 1 presents a typical view of a sanitary landfill with geosynthetics and Table 1 summarizes the primary functions geosynthetics perform. Geosynthetics in landfill design greatly reduces the cost and construction time besides offering an excellent protection to environment. More information on some of the common types of geosynthetics and their testing and evaluation are contained in Venkatappa Rao and Suryanarayana Raju (1990). Lining systems play a key role in forming a barrier between the waste and environment. They are one of the main elements in an engineered landfill. Liner systems envelop the waste and isolate it from direct contact with the environment. Such systems should remain functionary for the service life and post closure period of the landfills. Basically there are three kinds of lining systems - viz. basal lining, side lining and top lining or top capping, as shown in Figure 2.

Basal Lining System

The use of a basal lining system is to protect the subgrade from leachate which invariably generates from waste. Typical components of the liner systems are given in Figs. 2, 3 and 4. In the basal lining system the mineral sealing layer aids in (after GLR, 1993)

- minimising seepage and diffusion,
- resists erosion and water penetration,
- resists leachate and other physico-chemical effects like swell/shrinkage, seal healing, absoring heavy metal etc.

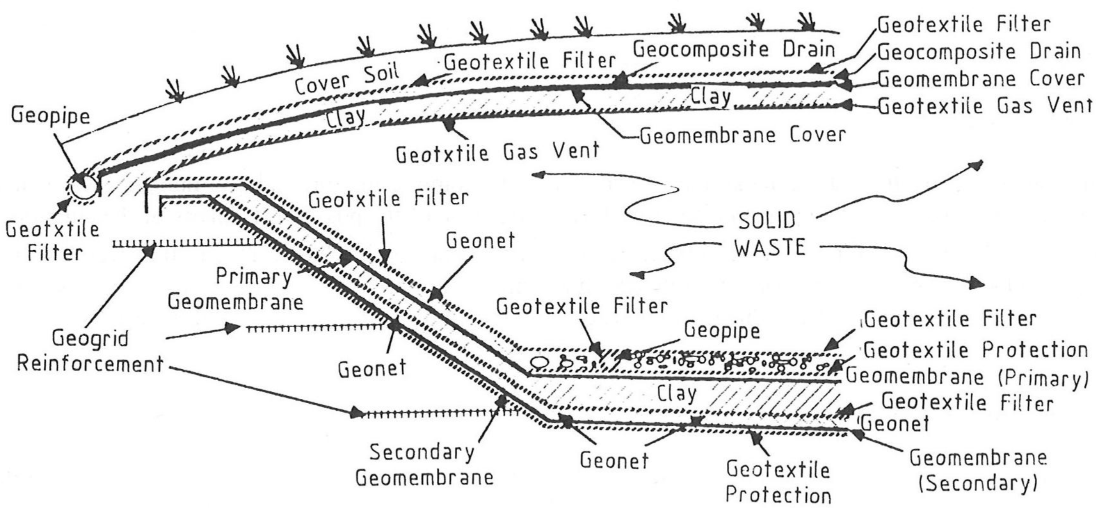

Figure 1: Sanitary Landfill with Geosynthetics
(After Koerner 1992)

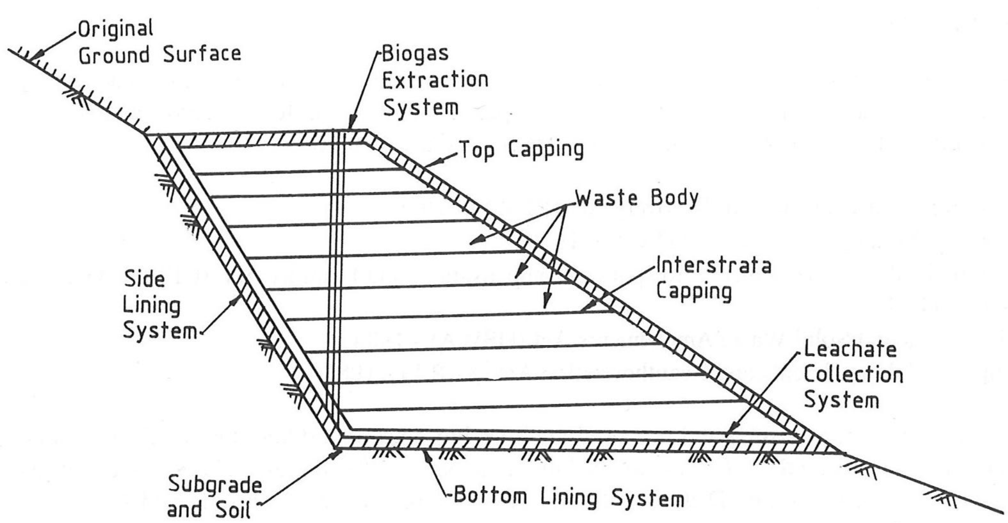

Figure 2: Sloped Landfill

On the other hand the geomembrane provides an impermeable barrier and is expected to be non-susceptible to long term chemical changes in its immediate environment and or the stresses caused by settlement of the subgrade/mineral sealing layer. A liner is permitted to accept contaminants into it but not allowed to migrate the contaminants through it. Due to this concern in addition to the clay liner a geomembrane is also included. There may be a protective layer over geomembrane layer comprising of geotextile which helps in redistribution of concentrated stresses over the geomembranes may be due to the angular aggregates of the drainage blanket. Figure 4 shows typical components of the composite basal lining system.

Side Lining System

The components of the side lining system are similar to the components for the basal lining system (Figs. 2 and 3). Side lining system poses peculiar problems. Because of the possible steepness of the cut slopes (say about 30^{o}), it is quite difficult to place adequately compacted clay liners Due to this prefabricated products like geomembranes, geocomposite clay liners are being preferred. Geotextile (protective layer) - Geomembrane - compacted clay liners are potentially the weak link of the system with regard to stability conditions.

Surface Lining or Top Capping

The landfill which was filled to its capacity ultimately requires to be covered. The covering of landfills requires a ideal liner system which will provide the dual functions of containing the waste materials while inhibiting the infiltration of precipitation and the ingress of vegetative and animal life. This system needs to be self-sustaining and hence must be resistant to external forces, which could lead to deterioration of the containment. Figures 5 shows the components of the top capping system as suggested by Jessberger (1994b) for waste of class II (organic content more than 5%) and class I (organic content less than 3%) respectively. The compacted soil liners are subjected to desication and shrinkage, whereas the other two systems perform better in this respect. The substitution of earthen layers with multilayer geosynthetic liners will no doubt induce beneficial extra storage.

U. S. REGULATIONS

Beginning in the mid-1970's, the United States developed comprehensive legislation to address municipal and hazardous waste disposal for existing and proposed facilities and for closed or abandoned facilities. The most important environmental laws that were enacted are as follows:

- Resource Conservation and Recovery Act (RCRA) - 1976
- Toxic Substances Control Act (TSCA) - 1976
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also known as Sperfund - 1980
- Hazardous and Solid Waste Amendments Act (HSWA) - 1984
- Superfund Amendments and Reauthorization Act (SARA) - 1986

RCRA deals with the existing and proposed facilities but does not address the problems associated with abandoned or inactive sites. RCRA is divided into nine parts or "Subtitles". The Subtitle C deals with the hazardous waste and subtitle D deals wit solid or municipal waste. Subtitle D and C are explained in detail below.

Subtitle D Program

The RCRA subtitle D program establishes minimum national criteria for all municipal solid waste

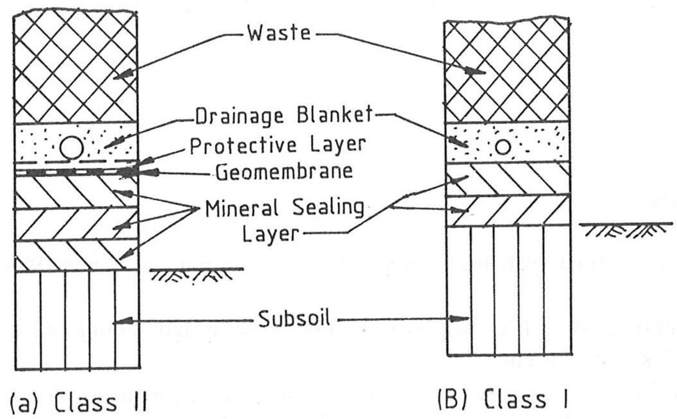

Figure 3: Basal Lining Systems for Class II and Class I Municipal Waste
(After Jessberger (1994))

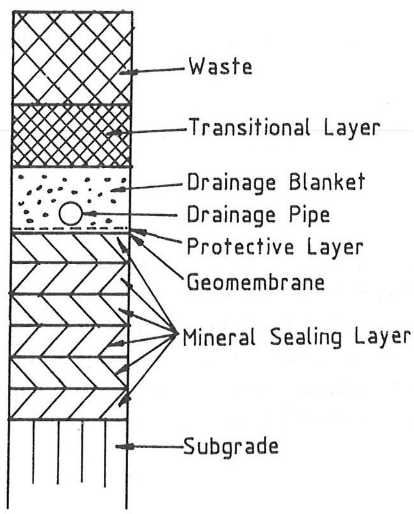

Figure 4: Components of Composite Basal Lining System
(After GLR (1993))

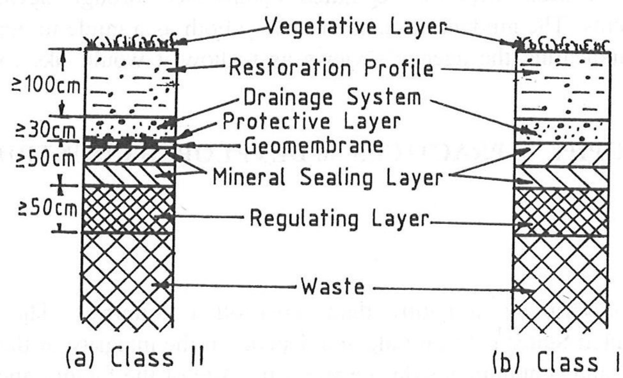

Figure 5: Top Capping System for Municipal Waste
(After Jesserberger (1994))

landfills to ensure the protection of human health and the environment. The program outlines the following main criteria:

- Location Restrictions
- Operating Criteria
- Design Criteria
- Closure and post-closure care
- Financial assurance criteria

Some requirements of the liner system are (Koerner 1994; Sharma and Lewis 1994):

- A leachate collection system located above the liner system and should be capable of maintaining a leachate head of less than 30 cm
- The liner system should be a single composite liner, in which a geomembrane of 30 mil thick should be placed over compacted clay liner. A 60 mil thick HDPE can be used in place of a 30 mil thick geomembrane.
- The compacted clay liner must be 60 cm thick and of permeability of $1x10^{-7}$ cm/sec or less.
- The cover system must have an erosion layer of a minimum 6 inches of earthen material underlain by a infiltration layer.
- The infiltration layer must consist of a minimum of 18 inches of earthen material that has permeability of less than $1x10^{-5}$ cm/sec.

Figure 6 shows the liner and cover system for a Municipal Solid Waste Landfill (MSWLF).

Subtitle C Program

The RCRA subtitle C program establishes minimum national standards to define acceptable management of hazardous waste. For hazardous waste landfills, double liners are required. The double liners include a top liner (a geomembrane) designed to prevent the migration of hazardous constituents and a composite bottom liner system consisting of a geomembrane underlain by at least 3 feet of compacted soil material having a permeability not exceeding $1x10^{-7}$ cm/sec. The closure cover requirement for a hazardous waste landfill is more stringent as opposed to a MSWLF as shown in Figure 7.

EPA Guidance Documents

Environmental Protection Agency (EPA) has developed "Guidance documents" which probably have more impact on the day to day activities in the practice of environmental geotechnics than do the regulations themselves. The EPA deals with the regulated community through devices known as Administrative Guidance Documents. The guidance documents serve both as a guide to agency staff and to the regulated community by indicating the agency's views as to how it would like to see the laws implemented.

COMPARISON and PHILOSOPHY of PRACTICES in DEVELOPED COUNTRIES

(Adopted from Brumund 1994)

United States

The US regulations are very prescriptive in nature than most other countries. The basic landfill containment philosophy in the United States is to provide and depend on the integrity of the bottom liners to prevent the release of leachate and contaminants during the active life of the facility and post-closure period. During this period of time, any leachate in the landfill must be evacuated from a primary leachate collection system. Since landfilling of liquids is not permitted, leachate generated through rainfall is

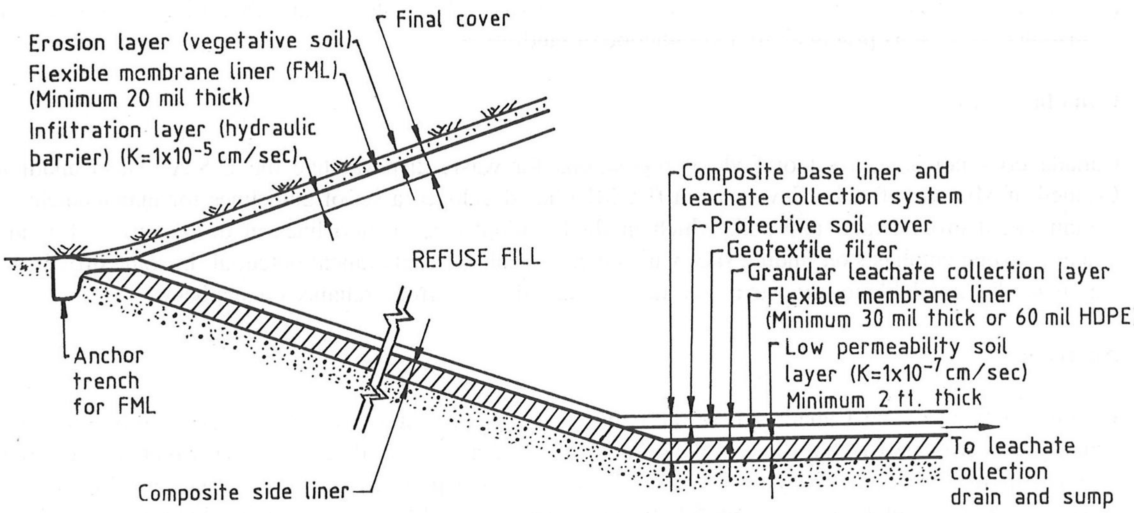

Figure 6: Subtitle D Landfill
(After EPA, adopted from Sharma and Lewis 1994)

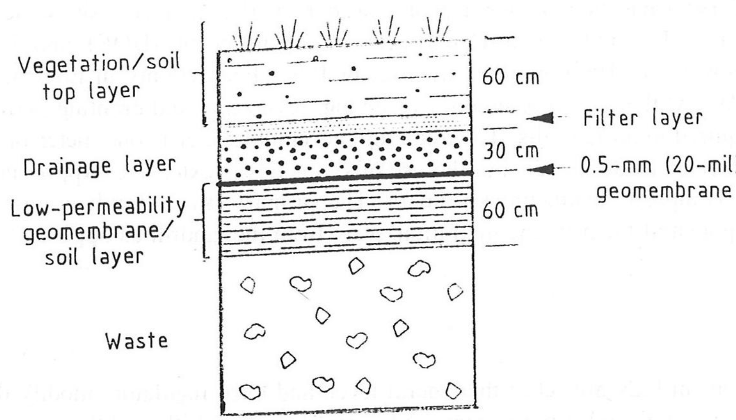

Figure 7: USEPA-Recommended Cover for Hazardous Waste
(From Landreth and Carson 1990)

minimized through a final cover system after closure. The current philosophy is to depend primarily on the engineered barriers as liners for landfills.

The current regulations require that hazardous waste landfills have two or more synthetic or synthetic/clay composite liners in landfills. The use of at least one synthetic or synthetic/clay composite liner is required in most municipal solid waste (msw) landfills. There are limitations on the types and concentrations of the wastes that can be landfilled. The regulations also require that a high quality cover be installed as soon as practical after completion of landfilling.

Canada

Canada does not have a set of Federal regulations for waste disposal like the U.S.A. The Canadian Council of Ministers for the Environment (CCME) has developed a set of guidelines for management of contaminated groundwater and soil, which might be adopted as a guidelines in the country. Canada places a strong emphasis on finding sites with superior geologic containment potential. In some provinces, clay is readily available to serve as a liner material and there is strong reliance on synthetics.

Australia

In contrast to U.S. and Canada where the emphasis is on protecting the groundwater, this is not the primary concern in Australia. Most of the groundwater in here is too saline to be used either for irrigation or for drinking. Here, they rely on common sense in issuing permits as opposed to being driven by a consistent set of regulations. For landfills liners are not required but are now generally being considered if not expected. Very few municipal solid waste landfills are synthetically lined. Most of the tailings and sludge containment systems are synthetically lined. No guidelines are available regarding post-closure care. However, proper surface drainage and 0.5 m thick earthen material as closure cover is considered sufficient.

United Kingdom

The Clean Air Act of 1956 has bought out a pronounced reduction in inert ash waste as a part of household waste in UK. England has a Department of Environment (DOE) and has passed an Environmental Protection Act in 1990 and a Water Act in 1991. Each county in England has a Waste Regulation Authority (WRA) that is responsible for receiving, reviewing, and granting permits to operate landfills. Liners are required in all landfills. The minimum acceptable liner is one meter of clay having a coefficient of permeability of $1x10^{-9}$ m/sec, but the use of synthetics is extensive. Approximately 70% of the new landfills have composite synthetic/clay liners. The primary driver for liner installation is the desire to minimize the potential for methane migration away from the landfill as opposed to groundwater protection.

Italy

Environmental regulations in Italy are set at the federal level, and local regulators modify the application of laws to fit local conditions. Clay liners are commonly provided in landfills and the need for such liners is largely driven by the hydrogeologic considerations. The use of the synthetics as liners is almost mandatory, but the use of synthetics is not common in closure covers. There is little emphasis on finding sites offering superior geologic containment potential.

In Italy, the construction and maintenance of a waste landfill must be designed in accordance with D.P.R. 915/83 national act (Calare et al. 1996). The legislation deals with many aspects of landfill construction, with particular attention to the possible types of waste that can be stored, and on the documentation it is necessary to provide. For the capping it is required that the lining system shall be of 1.00 m of clay with a maximum permeability of $1x10^{-6}$ m/s, or any other material with a permeability of coefficient equal to

1.0 m of caly. On the top of the lining system it is necessary to have an adequate protection layer and a final top soil layer.

Germany

The environmental regulations in Germany are very different from other European countries. Solid waste is regulated at both the Federal and State level. Germany encourages locating sites offering superior containment potential and in doing extensive site characterization studies. The primary factor for an engineered landfills is to protect the groundwater, similar to the U.S.A. The standard liner system consists of a synthetic/clay composite employing typically one meter of clay with a permeability of metes per second. Closure cover systems typically incorporate synthetics in the closure cover.

SOME CONSIDERATIONS FOR INDIA/DEVELOPING COUNTRIES

In the above section, environmental regulations and associated philosophy of the developed countries regarding waste management has been explained. However, in the case of developing countries such as India, there is a need to understand local social, cultural and development standards and customs, as well as have an awareness of more obvious resource limitations which often exist (Campbell 93). Every developing country has unique needs in waste management, and there is no necessity of "Technology Transfer" from the more industrialized nations. For example, in India, manual techniques are extensively used in the collection of garbage and in construction and there is no need to improve in this area by utilizing mechanized equipment.

In India, rural population is larger than the urban areas and the potential overall pollution load to the environment could be more significant from the larger bulk of the rural wastes generated. Efforts should be made to adequately characterize the waste streams (such as characteristics, type and quantities of the waste generated) to facilitate the development of environmentally sound procedures for waste collection and in establishing appropriate waste treatment/recycling and/or disposal needs (Campbell 1993).

Additionally, less attention is given to industrial emissions, which frequently represents the major source of environmental damage. The current practices of discharging liquid effluents directly into rivers and domestic waste waster treatment plants has to be changed immediately. In developing countries such as India, industrial waste management is more urgent and complex issue than managing domestic waste. Effective management of the industrial waste should be the priority and is the most critical element of a good waste management strategy.

In India, geosynthetic technology is being increasingly accepted in the engineering profession through concerted efforts of researchers, academicians and industry. However, there is little or no knowledge of solid waste management procedures that would decrease the threat to groundwater pollution. The necessary resources and established technical infrastructure are often not available to ensure efficient operation, or indeed to ensure any significant environment benefit. In our country, waste management activities come under the responsibility of a large number of very local administrative units which leads to problems of appropriate resource availability. In addition, India's most of the municipalities have little operational budget to manage the waste disposal facilities.

CONCLUDING REMARKS

In India, climate will vary substantially between the regions as well as between seasons. This coupled with the social differences can complicate the waste generation picture, at least for the composition of domestic wastes. Heavy rainfall and flooding are both major difficulties that must be dealt with in the design, construction and operation of landfills in India. Most of the rain falls during heavy thunderstorms in rainy season. Keeping the above factors in mind, perhaps a beginning can be made by considering the following zones in India:

1. Indo-gangetic alluvial belt, covering cities like Delhi, Kanpur, Chandigarh, Allahabad and Patna - having the same kind of subsoil profile as well as climatic conditions.
2. In the black cotton soil regions of Gujarat, Maharashtra, Madhya Pradesh and part of Andhra Pradesh where the climate is more arid.
3. Lateritic regions, say, in Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Goa etc. wherein the rainfall is heavier and there is marked weathering of grainitic soils coupled with high water table.

In addition, the following factors may be kept in mind:

- To begin with there should be streamlined efforts to characterize the waste streams generated in various parts of the country.
- There should be a proper landfill operation plan to reduce the quantity of surface water and groundwater that is being contaminated.
- Similar to other countries, a mechanism should be developed for permitting landfill facilities.
- For hazardous waste disposal, in particular, a mechanism should be developed to generate the necessary funds from the industrial counterpart contributing to the waste.

It is thus necessary to establish guidelines for MSW and HSW in the country keeping in view the economic considerations and technical issues described in the paper.

Table 1: Functions of Geosynthetics in Landfills
(After Koerner and Fahmy, 1993)

	Primary Function				
Type of GS	Separate	Reinforced	Filter	Drain	Barrier
GM					*
GT	*	*	*	*	
GN				*	
GP				*	
GC				*	
GG		*			

GM - Geomembranes; GT - Geotextiles; GN - Geonets; GP - Geopipes; GC - Geocomposites; GG - Geogrids.

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