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A Case Study of a Secured Landfill

Sandhya Rani R
Department of Civil Engineering, MVSR Engineering College, Hyderabad, Telangana, India

ABSTRACT

Solid waste disposal in isolation from the environment is a burning problem in urban areas. Landfills are preferred option for this problem and play a significant role in waste management practice. The investigation is required to provide information and data necessary to design an acceptable landfill and monitoring system for a particular site. A case study of a landfill designed and executed at Vizianagaram town, which is first of its kind in Andhra Pradesh, is presented here as a case study. The Vizianagaram Municipality has carefully evaluated the appropriate landfill facility along with a leachate treatment plant to cater for the disposal of municipal solid waste. To meet these requirements a composite liner system comprise of a 900mm thick locally available sandy clay compacted to a permeability less than 10^{-6}mm/sec and a HDPE liner with permeability less than 10^{-11}mm/sec above which a complete drainage system is placed. The case presented here is performing well since inception for the behavior of clay liner and on leachate-liner soil interaction.

Keywords: Solid Waste, Secured Landfill, Leachate, Clay Liner, HDPE Liner.

I. INTRODUCTION

The impact of dumping municipal solid waste on land without any containment include Ground water contamination through leachate, Surface water contamination through runoff, Air contamination due to gases, litter, dust and bad odour, Other problems due to rodents, pests, fire, bird menace, slope failure, erosion etc. Landfills are designed and constructed to eliminate any possible adverse impacts and for occupational health and safety. The generation of leachate as well as gas from landfills influences landfill design and operation. Leachate and gas production are influenced by waste type, the local weather and the landfill operating methodology. One can visualize a landfill to be a biochemical reactor with solid waste and water as major inputs and leachate and landfill gas as the major outputs. Leachate and landfill gas control systems are used at all engineered landfills to prevent unwanted movement of these outputs, vertically downwards into the surrounding soil. Low permeability clays along with synthetic liners are generally used as a barrier between the waste and subsoil to contain leachate [1].

Locally available natural clays are used as liner material. If the local soil or soil from nearby areas does not possess the property of low permeability, additives in the form of natural clays or commercially available clays may be mixed with local soils to form amended soil liners. A leachate collection and removal system is placed over the liner system. The landfill cover system, consisting of a package of different mineral layers is exposed to the atmosphere. The moisture content and the matric suction of the soil layers undergo changes during the annual weather cycle [2]. In addition to liner and leachate collection systems, final cover system for a landfill is a critical component that needs to be specifically engineered not only to separate the buried waste from the external environment, but also to restrict infiltration of surface water into the waste and occasionally to control release of gas from the waste.

The efficiency of any landfill for solid waste disposal depends upon selection of proper site and there are several issues that have impact for site selection. The ultimate aim is to select a site where the greatest protection to the environment is provided. The selection process involves several stages with a purpose to narrow the list of possible sites. A location criterion may be specified by a regulatory agency (ex. Pollution control board). In the absence of regulatory requirements the following criteria are suggested.

- ✓ No landfill should be constructed within 200m of any lake or pond/ 100m of navigable river or stream/ a 100years flood plain/ 200m of the right of the way of any state or national highway/ 300m of a public park/ 500m of any water supply well.
- ✓ A landfill should not be constructed in areas where water table is less than 2m below the ground surface.
- ✓ A landfill should not be located in potentially unstable zones such as landslide prone areas, fault zones etc.
- ✓ A landfill should have a buffer zone around it, upto a distance prescribed by regulatory agencies.

It is absolutely essential to site a landfill within a restricted zone then appropriate design measures are to be adopted and permission from the regulatory agency should be obtained. A landfill site with low environmental impact and high social acceptance and low costs is the most desirable.

Before the main design of a landfill, it is important to develop the operating methodology. A landfill is operated in phases because it allows the progressive use of the landfill area, such that at any given time a part of the site may have a final cover, a part being actively filled, a part being prepared to receive waste, and a part undisturbed. The term "phase" describes a sub-area of the landfill. Each phase is typically designed for a period of 12months. Due to this phased operation, keeping areas of active filling to a minimum reduces the generation of leachate.

The main objective is to study the basic design and execution of a secured landfill and a leachate treatment plant to cater for the disposal of Municipal solid waste (MSW) generated within the limit of Vizianagaram Municipal Corporation. Vizianagaram municipality generates about 110 tons/day of MSW on average. The waste is collected (generally from bins, restaurants, market yards and streets) and transported by the municipality or by its contractors. The waste is received at the dumpsite and is disposed off. It is required to dispose off the waste safely without causing public inconvenience otherwise, the dumped waste cause contamination of ground water and may also cause serious health problems. For this the municipality complied with the "Management and Handling Rules 2000" and hence established infrastructure required for the construction of secured landfill for the disposal of municipal waste. The municipality has established facilities for recovery of recyclables and organic wastes that can be converted to compost and the balance being disposed off into the secured landfill. The quantity of waste to be land filled would therefore be 47% of 110 tons/day i.e. 52 tons/day approximately which also includes about 15-20% moisture. This moisture will subsequently be removed from the system as leachate. The execution of the work includes design of the secured landfill facility, site development of approximately 3 acres, earth work excavation, preparation of sub-base, establishment of base liners comprising of clay liner, HDPE liner, drainage systems and geo-textile, establishment of leachate treatment plant.

II. MATERIALS AND SPECIFICATIONS

The locally available sandy clay was used for the base liner system. The properties of sandy clay are as shown in Table 1.

Table 1. Properties Of Sandy Clay

S.No	Description	Value
1	Sand	35%
2	Silt	40%
3	Clay	25%
4	Liquid limit	34%
5	Plastic limit	17%
6	Plasticity index	17%
7	Coefficient of permeability	$3.2x10^{-8}$ m/sec
8	IS Classification	CL
9	Free swell index	Nil
10	Optimum moisture content	15.5%
11	Maximum dry density	1.82g/cc

The high density polyethylene (HDPE) membrane having coefficient of permeability of 10^{-14} m/sec was used for the composite liner system along with the sandy clay. The specifications of the HDPE geo-membrane are as shown in Table 2. These specifications are as given by the manufactures.

Table 2. Specifications Of Hdpe Geo-Membrane

S.No	Description	Value
1	Thickness of membrane	1.5mm
2	Density	0.942gm/cc
3	Melt flow index	2.0-3.0gm/10min
4	Tensile strength at yield	25N/mm
5	Elongation at yield	12%
6	Tensile strength at break	45N/mm
7	Elongation at break	700%
8	Puncture resistance	500N
9	Tear resistance	200N

Slotted pipes were used for the collection of leachate. These are HDPE pipes embedded in drainage layers of sand/gravel. Graded sand/gravel having a high permeability of 10^{-2}cm/sec was used as a drainage layer. A geo-textile was placed above this drainage layer. It acts as a filter or barrier between the waste and the drainage system.

III. DESIGN FEATURES

A municipal solid waste landfill is a system comprised of three primary subsystems: (i) the hydrogeology and barrier system below the waste (this includes side slopes below waste); (ii) the waste and landfill operations; and (iii) the landfill cover and landfill gas control system [3]. The most important design feature of a landfill is its volume, which in turn depends on the area available, depth at which the waste is placed and the depths of soil cover over the waste. The principles have been adopted in designing the landfill were minimize the possibility of contaminating surface and ground water, control over gaseous emissions, maximize resource productivity and eliminate any possible adverse impact. To meet these requirements the base of the landfill has to be designed as an engineered liner constructed prior to the placement of waste.

A. Base liner system

The base liner for the executed landfill containment system was a composite liner with one layer of synthetic geo-membrane and clay. Adequate leachate collection system has incorporated at the base to collect and remove the leachate. These should incorporate HDPE pipes embedded in drainage layers of gravel. The composite liner should comprise of a 900mm thick locally available sandy clay compacted to permeability less than 10^{-9}m/sec above which a complete drainage system was placed. The permeability changes with change in pH value and was found that increase in permeability is high in alkaline medium [4]. A leachate collection and removal system has placed over the primary liner to collect and remove any leachate generated by infiltration of precipitation or by the moisture entrapped in the waste. Above the drainage system of the primary liner has placed a geo-textile filter to act as a filter / barrier between the waste and the drainage system. This entire system would make the base liner a composite liner. The cross-section of the landfill is presented in Figure 1. A view of landfill with HDPE geo-membrane is shown in Figure 2 and the anchor trench on all sides of landfill is shown in Figure 3.

B. Leachate collection system

Leachate is collected by a network of lateral and header HDPE pipes embedded in a drainage layer, all of which shall eventually drain into a leachate collection sump. The collected leachate shall be transferred to a leachate treatment plant. It is required to ensure that there is no more than a limited head of pressure above the base liner to cause leakage of liquid from the base of the landfill. The maximum pressure head designed in the landfill should be limited to 300mm.

Drainage is affected by a layer of about 300mm thick of graded sand / gravel placed over the entire base of the landfill. Within this layer a network of HDPE pipes were placed to collect leachate and graded towards the collection sump at not less than 2% slope. The pipes were typically perforated only over the upper half to allow the leachate to enter the pipe and thereafter to be contained within the pipe network system. The layout of the pipe network generally includes sufficient redundancy to ensure that if a blockage occurs somewhere in the network the leachate simply backs-up a little then flows into the system a little further up-gradient. Slotting area of the pipe should be done only on the top 120^{o} portion of the pipe and to an extent of 100sq.cm per running meter of the pipe. The slotted HDPE pipes for leachate collection are shown in Figure 4.

The pipe should have sufficient strength to withstand the load imposed by the overlying waste and the earth moving activities associated with the placement and the compaction of the waste (6kg/sq.cm). The main pipe (headers) feeding leachate to the sump should have the capability to be cleaned out in case of clogging. However, the design should include sufficient redundancy of pipe work to ensure alternative drainage paths were available in the event of localized clogging of any part of the system.

Quantity of leachate generated from landfill depends on rate of infiltration given by

$$I = P - PC_{R/O} - AET +/- S$$

Where, I – Rate of Infiltration, P – Precipitation, $PC_{R/O}$ – Coefficient of Runoff, AET – Actual Evapo-Transpiration, S – Soil moisture content retention capacity.

Empirically,

For capped portion of landfill:	$I = 0.01P$
For Uncapped portion of landfill:	$I = 0.7P$
Landfill with temporary cover:	$I = 0.3P$

Based on the landfill sizing of 55x55m the amount of leachate generated within this facility should be 2117m^3 (worst case based on the complete uncapped portion) and adding the moisture of 15% of the waste 1275m^3 the total leachate was expected to be 3500m^3 per year with safety. This translates to 10m^3 per day and this should be the capacity of the leachate treatment facility for the proposed plant.

C. Leachate treatment plant

The leachate treatment plant should be an activated sludge as the characteristics of leachate would typically reflect the waste characteristics and were expected to be biologically degradable in nature. The basic components of the plant should include Collection tank, Primary settling tank, Aeration tank, and Secondary settling tank/clarifier, Sludge drying beds, Motors and pumps. The treated leachate would be discharged to drains or sewers along with the sewage collection system of the city, while the sludge generated would be processed and disposed back into the landfill. The details of the capacity of landfill are presented in Table 3.

Table 3. Capacity Of The Landfill

S. No	Description	Value
1	Volume of landfill created	10176 m^3 per 8177 tons
2	Density of waste + Soil (post compact)	0.9 tons/m^3
3	Soil cover (daily/intermitted)	0.12
4	Quantity of waste per day	52 tons/day
5	Moisture content which will come out as leachate	15%
6	Life of facility	186 days @ 44 tons/day

IV. CONCLUSIONS

Landfills are preferred option for disposing the waste in isolation from the environment and play a significant role in waste management practice. The generation of leachate as well as gas from landfills influences landfills design and operation. Low permeability clays along with synthetic liners are generally used as a barrier between the waste and the sub soil to contain leachate. Previous studies shown that clay compacted to a permeability of less than 10-6mm/sec form a good barrier to leachate and also cost effective. Although, any natural soil cannot meet all the specifications of clay barriers / liners, the soil that meet the permeability requirement can be used as a liner. In addition to liner and leachate collection systems, final cover system and stability of both landfill and excavated slopes are also need to be specifically designed. Study of the behavior of leachate contaminated soil over a period of time gives an idea about the changes in properties based on which designs have been finalized and they last long. If the changes are not acceptable, certain remedial measures or precautions are to be taken to minimize the adverse effects. An earnest attempt was made in the present case investigation to achieve these objectives.

The sandy clay used for clay liner in the case study is very much suitable as clay liner in its grain size, plasticity and hydraulic conductivity. Compaction on ±2% of OMC in standard compaction shall yield satisfactory permeability as per specifications. In addition an HDPE membrane was used to arrest seepage and slotted HDPE pipes are used for collection of leachate to a sump. It was therefore felt that a 600mm thick liner (in place of 900mm thick) should have been adequate bringing in considerable economy. This landfill is performing well since inception for the behavior of clay liner and on leachate-liner soil interaction.

V. REFERENCES

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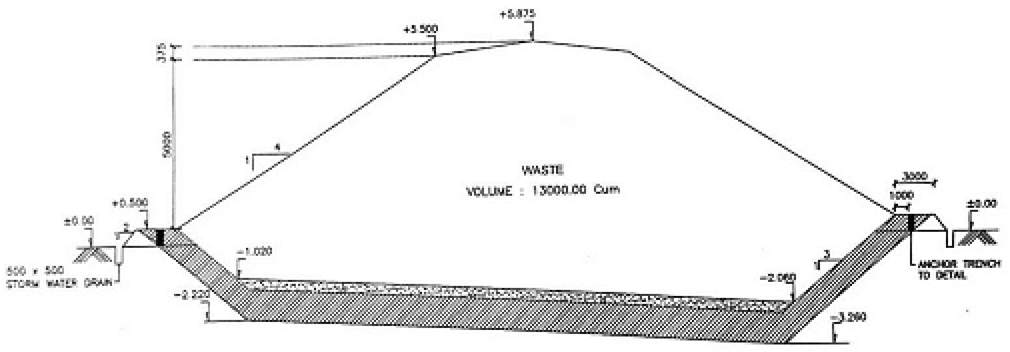

Figure 1. Cross-section of Landfill

Figure 2. A view of Landfill with HDPE Geo-membrane

Figure 3. Anchor Trench

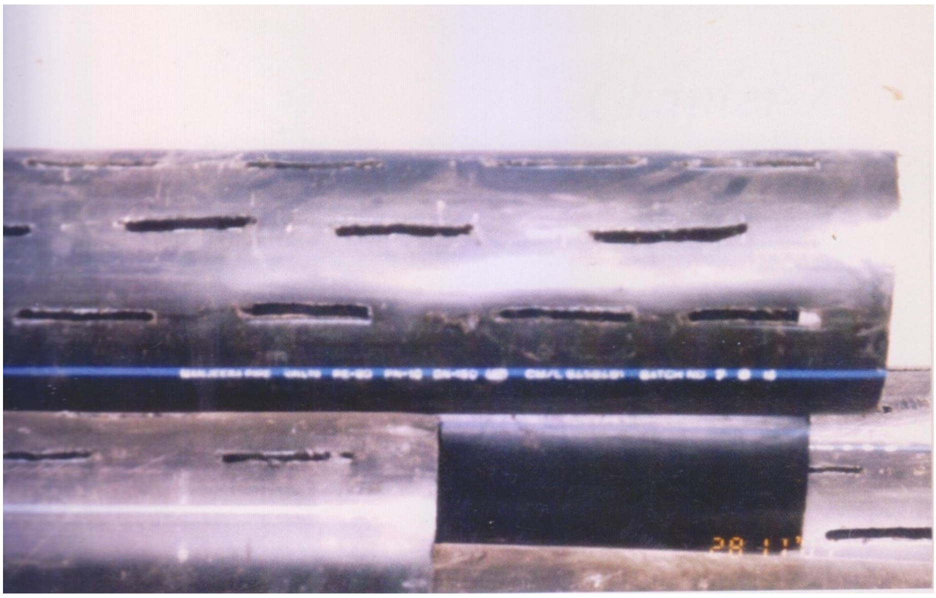

Figure 4. Slotted HDPE Pipes for Leachate Collection