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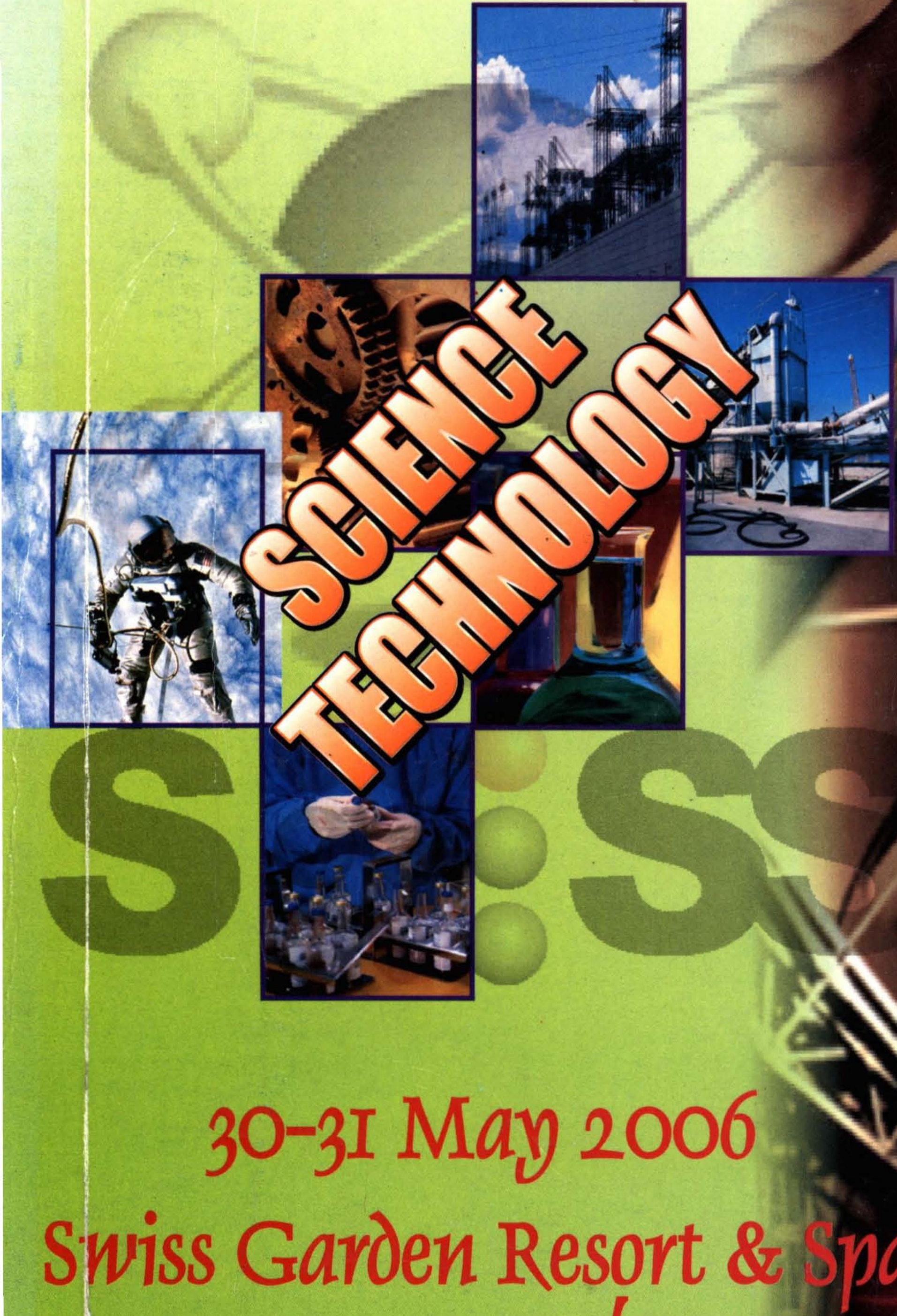

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The Fundamental Systems in a Modern Constructed Municipal Solid Waste

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ABSTRACT

The volume of municipal waste generated is mainly attributed to the increase in population. In Malaysia, landfilling sites for the disposal of MSW are rarely operated in a sanitary manner. They are basically an uncontrolled open dumping sites rather than a properly engineered sanitary landfill and with a population of more than 20 million and a waste generation rate of 1kg/capita/day is going to generate an enormous amount of volumetric solid waste in years to come. One of the pressing problems facing municipalities is a safe and a long disposal of waste in a landfill which control and minimize the environmental problems created such as air pollution and the possibility of ground water contamination due to liquid leachate. This paper deals only with the fundamental systems in an engineered constructed MSW landfill to contain the above problems. These are leachate containment system (barrier), leachate collection and drainage systems, landfill gas management system and finally the cover (cap) system. It should be emphasized here that this is only a mere general overview and discussion of a practical as well as theoretical should be of a modern MSW landfill.

Key words: *Base liner system, Geosynthetic material, Leachate collectionsystem, Landfill gas management, Cap system*

Introduction

The volume of MSW will continue to rise while unsafe landfill and sometimes illegal dumping of waste will remain a problem. Land filling despite several drawbacks is generally the most economic alternative for MSW disposal which accounts for its frequent application and it stands alone as the only waste disposal method that can deal with all materials in the solid waste stream. However, it must be made clear that MSW landfill in response to the hazard associated with the indiscriminate dumping of waste such as threatening public health and safety must be designed, constructed and operated in environmentally sound manner. It means that landfills controlled operation techniques such as daily cover, compaction and systems be provided to control not only problems associated with leachate that can cause ground water pollution but the production of methane gas which can create hazardous conditions if it rises to the surface. Basically there are four fundamental systems or facilities that need to be addressed and complemented in the proper construction of an engineered MSW landfill.

These are base liner barrier, cap system (cap layer facility), leachate containment and collection system and lastly the gas management system. A typical conceptual layout of a MSW sanitary landfill with the four systems mentioned is shown in Figure 1.

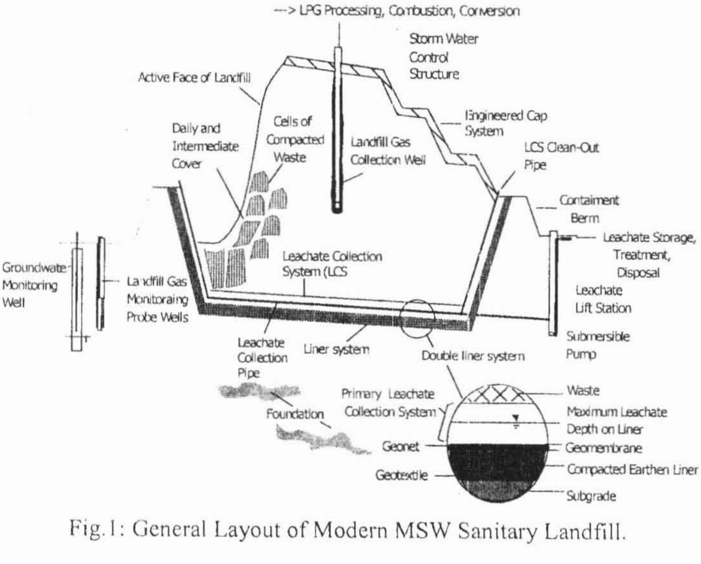


Fig.1: General Layout of Modern MSW Sanitary Landfill.

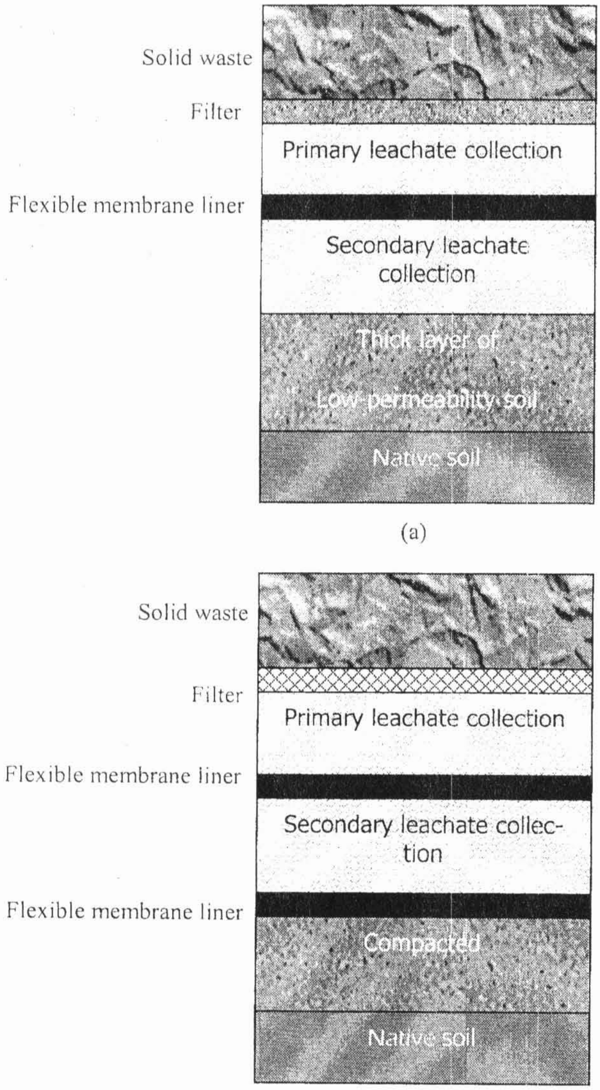
Landfill Objectives

The goal of modern engineered landfill is to reduce the risk that the waste pose to human and the environment by limiting their mobility and to provide a safe and long term disposal of solid waste, hence, the term sanitary landfill which is often applied. The waste must be isolated from the environment and the emission of leachate must be controlled and collected so as to reduce the risk of groundwater pollution. MSW sanitary landfill should, therefore, be able to provide the most secure containment facility as possible, hence, most modern landfills better operated on containment, as opposed to natural attenuation type landfills. To a limited extent, land filling can also be considered as a valorisation process. Once collected the energy content from the emission of landfill gas (methane) can be exploited, so land filling could be argued to be a ***waste - to - energy*** technology. Once collected it makes sense to utilize the energy content of the gas where it can be produced in commercially exploitable quantities by having a proper landfill gas system facility (Peavy 1985).

Leachate Containment System (Base Liner Layers)

Leachate is generated in a landfill as a consequence of the contact of water with solid waste. It results directly from the moisture and decomposition of garbage and other putrescible material in the waste material and also from runoff or surface water that infiltrates the fill and percolates downward through the waste material. Leachate may contain dissolved or suspended material associated with wastes as well as many byproducts of chemical and biological reactions. MSW leachate varies in strength, a result of the biological activity occurring as the waste degrades and generally contains more pollutants than raw sewage. The threat of migration to the underlying soil and groundwater led to the concept of containment systems for modern MSW sanitary landfills. It involves the use of barrier layer or base liner, the primary function is to control the movement of leachate from being released to the groundwater. Barrier layers are constructed of material that posses a low permeability to water. The most common material is compacted clay. Clay soil as a liner material is generally favoured due to its ability to absorb and retain many of the chemical constituents found in leachate and for its resistance to the flow of leachate. This is because clay consisting of small particle size and hydraulic conductivity (permeability) of less than 1×10^{-6} mm/s offers a very good resistance to any flow movement. However, the use of combination composite artificial geosynthetics (geomembranes, geotextile, georids, geonets) and clay liners is gaining in popularity in the construction of most new MSW sanitary landfills. A geomembrane is a thin sheet of plastic that possesses the characteristic of being highly impermeable to water and resistant to chemical attack from the waste it is designed to contain. This synthetic material, usually made of high density polyethylene (HDPE) is sometimes called a flexible membrane liner (FML).The use of geosynthetic materials over clay presents some technical advantages: i) reduced thickness allowing additional volume for waste, ii) constancy of physical, hydraulic and mechanical properties and related control and iii) ease and reduced time of installation. Disadvantages of geosynthetic materials include more susceptible to leaks from damage during installation and their long term performance is uncertain. For these reasons the latest in landfilling lining technology seems to integrate artificial and natural liners but for application in Malaysia, natural clay liners normally offer the cheapest and most practical solution (Basri 1999). However the use of composite liner provides more protection and is hydraulically more effective than either type of liner alone.

An alternative to the composite liner system is the double liner system. A double liner consists of two barrier layers, with a drainage layer placed between. The upper and lower barrier layers may be either single or composite layers. In US, the minimum federal standard requires a double-liner system on the base. The drainage layer above the upper barrier layer is the primary leachate collection system and the drainage layer in between the two barrier layers is the secondary leachate collection system or leak detection system. Figure 2 shows two typical cross-section of base-liner system that US RCRA (Resource Conservation and Recovery Act) recommends for an engineered landfills.



(a)

(b)

Fig. 2: Recommended Base Liner Systems for Engineered Landfill. (US-EPA)

Leachate Collection Systems

Leachate that a landfill generates is intercepted by the barrier layer of the liner system and must be routed from the liner through the use of drainage layers. Leakage through a barrier liner can occur either as a result of permeation through the material or leakage through a hole or imperfection, increases with an increasing depth of leachate on the liner. Leachate collection systems are therefore designed to minimize the depth of leachate (i.e head) above the liner. In an engineered landfill it is usually directed to the collection system by gravity. In US, the RCRA (1985) landfill regulations limit the head of leachate to no more than 30cm (1 ft) at any given time. There are four parameters that have the greatest impact on head above the liner, the flow rate of leachate into the leachate collection system, the permeability of the drainage layer, the length of the drainage path and the slope of the liner.

The leachate collection system should be made of a material that has high transmissivity (i.e. permeability of 1 x 10^{-2} cm/s). In conventional design, the primary leachate collection system uses 60 cm (2 ft) thick, and the secondary leachate system uses 30 cm (1 ft) layers of a highly permeable, coarse material such as sand to establish the drainage path. In addition to carrying the leachate sand also protects the geomembrane from mechanical damage from equipment and solid waste (Cornwell, 1998). However this material is impractical if the slopes of the landfill are steep and an innovative method that is used on such slopes is to place a highly permeable coarse material on the base of the landfill, such as gravel, and the geocomposite material with high tranmissivity on the side slopes. These geocomposites can perform the drainage function and also permit designers to construct on steeper and longer slope angles. The synthetic material, geonet can be a suitable drainage layer. A geonet is a continuous extrusion of polymeric ribs. The ribs are at acute angles to one another and form large apertures in a net – like configuration. Geonets can be designed to provide the maximum flow channel capacity even with the stress of overburden. They are often sandwiched between two geotextiles to prevent fine materials or suspended solids from clogging the geonet.

The leachate pipes are generally installed in trenches that are filled with gravel. The trenches are generally lined with geotextile to minimize entry of fines from the liner into the trench and eventually into the leachate collection pipe (Bagchi 1994). Figure 3(a) & (b) show the typical trench details for the design of clay and synthetic membrane liners. The used of moulded gravel is to distribute the load of compaction machinery and thereby provides more protection for the pipe against crushing while geotextile which acts as filter should be folded over the gravel. A graded sand filter may be designed to minimize the infiltration of fines into the trench from the waste.

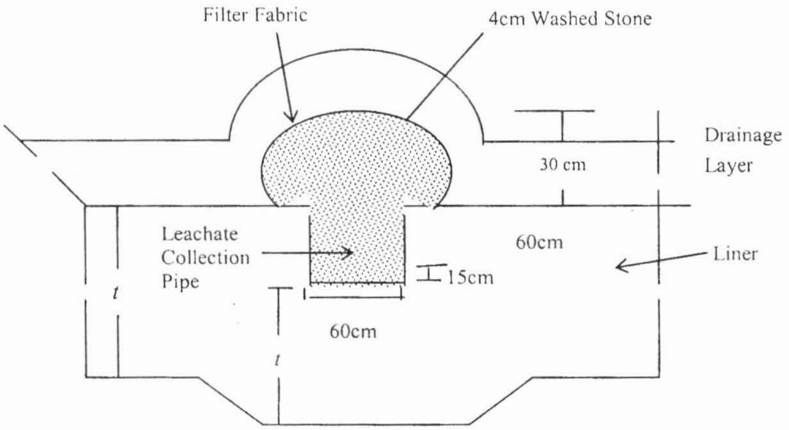


Fig. 3 (a): Leachate Collection Trench Detail

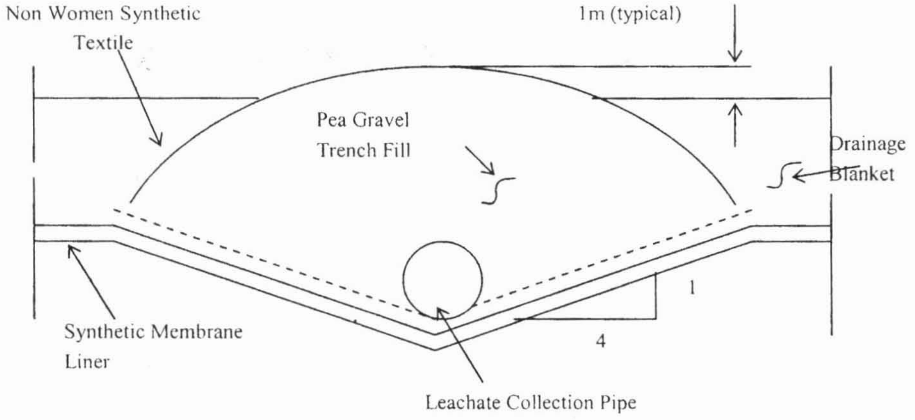


Fig. 3(b): Leachate Collection Trench for Synthetic Membrane Liner

The strength of a collection pipe must be checked to ascertain whether it will be able to withstand the load during both pre and post constructional periods and should be brought on the liner only when the trench is ready. The leachate collection system must periodically be verified and maintained the reason being that there do not yet exist set standards or recognized methods for the structural calculation of leachate collection pipes. This is to counter any possible interactions between the inhomogeneous wastes and construction component which might often incorrectly estimated or not even accounted for. The pipes wear factor should be taken into consideration for either HDPE or rigid earthenware and they must remain both functional over a long period of time. Thin – walled pipes with insufficient profile stiffness are not appropriate.

Landfill Gas Management System

The landfill gas is produced by the anaerobic decomposition of biodegradable organic material from the action of micro organisms. During the process of decomposition, significant portion of organics wastes are ultimately converted to gases end-product. The rate of gas production is a function of refuse composition, climate, moisture content particle size and compaction as well as nutrient availability. The production of biogas, where methane and carbon dioxide are the major components of end-product must be controlled and may result in an energy recovery opportunity. These are the main consideration of a landfill gas management system.

Landfill gas is typically 60 percent methane, 30 percent carbon dioxide and followed by other trace gases such as hydrogen sulfide, water vapor, hydrogen and various volatile organic compounds which make up most of the remaining volume. The production of landfill gases presents a new set of design challenges to control gas migration and collection of gas flow from the fill. Gas collection is to minimize emissions to the atmospheric for health and safety concerns, aesthetic as well as to minimize atmospheric degradation

Deciding on the wisest option for the landfill gas management facilities is very crucial since the facilities can be very costly. Venting options that are available include: (i) active venting with utilization (ii) active venting with burning (iii) passive venting or (iv) no venting. Active venting options are more expensive and less simple to install since it only involves the use of suction pumps to draw the gas. Passive systems are installed where gas generation is low and off-site migration of gas is not expected and generally suitable for small municipal landfills (up to 40,000m^3) and for most non-putressible containment type landfill.

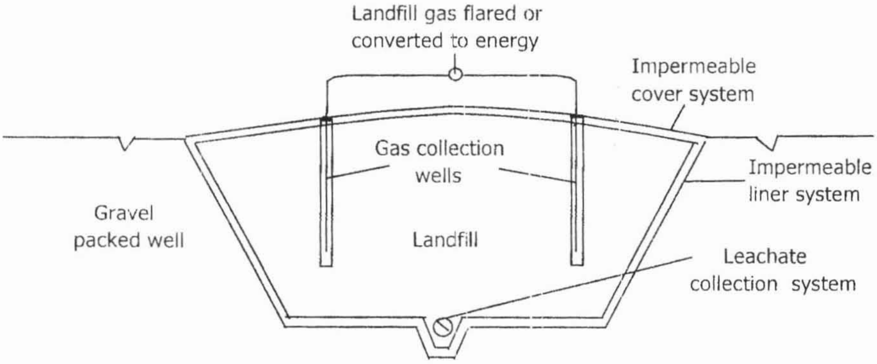


Fig. 4: Impermeable Liner

The movement of landfill gases through adjacent soil formations can be controlled by constructing barriers of materials that are move impermeable than soil before filling operations start (Figure 4). The use of geomembranes to limit the movement of landfill gases is more practical because the principal gases as well as the trace gases will and can diffuse through clay liners. While gas generated within the landfill will migrate toward a well due to the pressure difference between the landfill interior and the atmosphere, passive venting does not always result in large collection efficiencies.

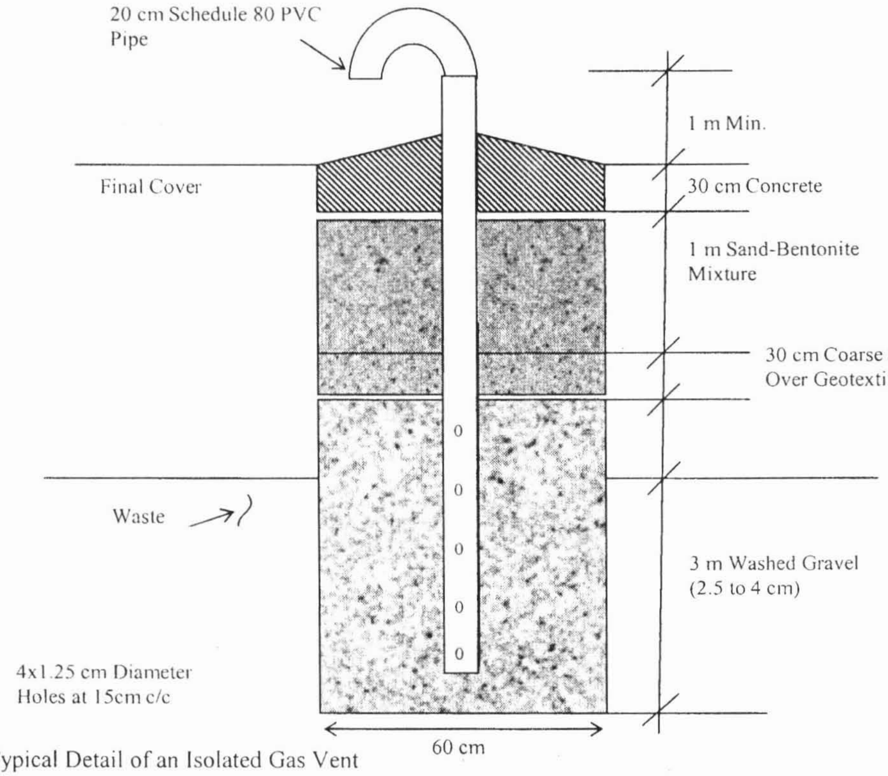


Fig. 5: Typical Detail of an Isolated Gas Vent

A typical detail of isolated passive gas venting system is shown below (Figure 5) and no design procedure is available to calculate the number of vents required, but one vent per 7000m^3 (~10,000yd^3) of waste is generally sufficient.

An alternative approach is to place a vacuum on the well thus creating a greater potential for gas removal. This normally is accomplished by connecting individual wells to a pipe network that is in turn connected to a blower. The blower induces a vacuum in the manifold and the wells extracting gas from the landfill interior and either delivers the gas for energy reuse purposes or to an on-site burner or simply releases it to the atmosphere. Whether the gas can be released to the atmosphere without burning depends on the followings;

(i) Chemical constituent of the gas. If hazardous air contaminants such as vinyl chloride or benzene are present then burning the gas is the preferred option. If such contaminants are absent, releasing the gas to the atmosphere may be acceptable in some (but not all) situations.

(ii) Landfill location. If the landfill is located near/within a community then burning is necessary because methane has an odor of its own that may create a nuisance condition.

It should be stressed here that the goal of an active landfill gas collection system is to remove the maximum amount of gas possible from the waste, thus minimizing migration to the atmosphere.

Cover/Cap System

The cap system for an engineered landfill shares many characteristics of base-liner system. The primary purpose of landfill cover among others are: (i) to minimize the infiltration of water from rainfall after landfill has been completed, (ii) to limit the uncontrolled release of landfill gases, (iii) to limit the potential for fires, (iv) to provide a suitable surface for the revegetation of the site and (v) to serve as the central element in the reclamation of the site. While no technical standards have been issued for the specific components of the cap system, the barrier layer in the cap system must not have a hydraulic conductivity greater than the bottom component of the liner system. US EPA suggested cap design is shown in Figure 6. It is made up of a series of layers, each of which has a special function. The barrier layer (geomembrane) is used to restrict the movement of liquids into the landfill and the release of a gas through the cover whereas the drainage layer is to transport rainwater that percolates through the cover material away from the barrier layer and to reduce water pressure on the barrier layer. The soil top layer/vegetation layer is to support the plants that will be used in the long term closure design of the landfill and to prevent surface soil erosion. However it must be emphasized here that, not all layers will be required. The requirements of the site dictate which layers are necessary.

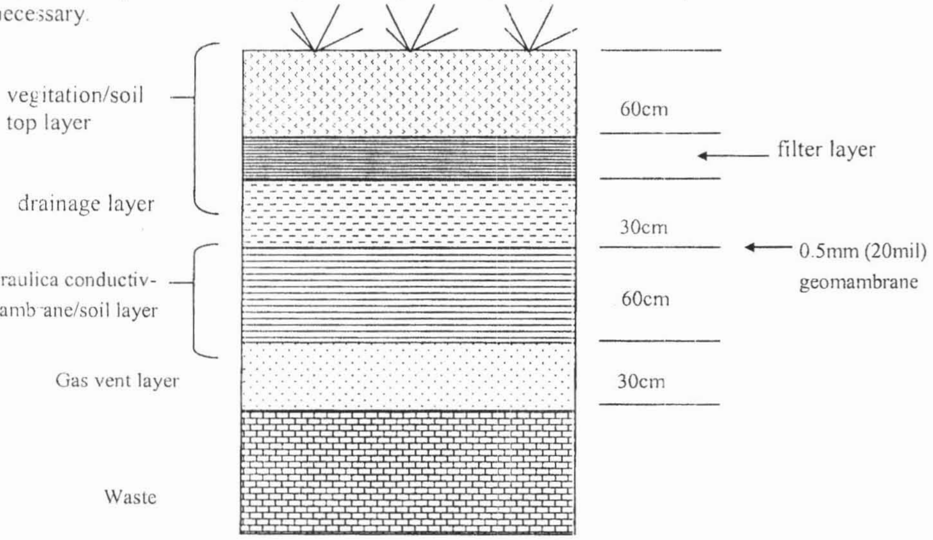


Fig. 6: EPA-US Recommended Landfill Cap System

Of the layer identified in figure above, the barrier (geomembrane) layer is the most critical. Although clay has been successfully used in many landfills as the barrier layer, a number of problems are inherent with its use. Clay is difficult to compact on soft foundation, compacted clay can develop crack due to desiccation, clay will crack due to differential settling, clay layer in a landfill cover is difficult to repair once damaged and clay layer does not restrict the movement of landfill gas to any significant extent. For these reasons, the use of geomembrane is recommended over the use of clay as a barrier layer in landfill cover.

For the conclusion it can be said that for the foreseeable MSW sanitary landfill sites are containment sites. It means that the waste's leachate and gas must be monitored and properly isolated from the surrounding environment. The objective of an engineered landfill is to minimize the environmental hazards caused by these two main waste products of landfill. The only environmental control that is going to minimize the hazards of leachate and landfill gases are the fundamental systems described above, since these are most critical components in the design and construction of an engineered landfill regardless of any design and constructions method adopted.

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