International Journal of Development and Sustainability
Online ISSN: 2186-8662 – www.isdsnet.com/ijds
Volume 2 Number 1 (2013): Pages 380-389
ISDS Article ID: IJDS12101901

Note on liners for containment of Leachate in sanitary landfills to enhance sustainable environment

Olusegun Omoniyi Ige *

Department of Geology and Mineral Sciences, University of Ilorin, Ilorin, Nigeria, P.M.B 1515, Ilorin, Kwara State, Nigeria

Abstract

Leachate from waste degradation creep to neighboring natural soil and water bodies in undersigned landfills and impairs the quality of environment expose to man. This paper deals with the selection of materials for sealing layers in sanitary landfills. This layer is the most critical component of landfills top and bottom covers. Commonly used liners in sanitary landfills are compacted natural low permeability clayey soils, geosynthetic materials or combination of the two. Geotechnical conditions for natural soils to be useful as liners are also presented.

Keywords: Sanitary, Landfill, Municipal, Geomembrane, Liners

Cite this paper as: IGE, O.O. (2013), "Note on liners for containment of Leachate in sanitary landfills to enhance sustainable environment", *International Journal of Development and Sustainability,* Vol. 2 No. 1, pp. 380-389.

* Corresponding author. *E-mail address:* vickyige2002@yahoo.com

1. Introduction

Age of waste generation is as old as the beginning of human civilization. The term 'waste' can be defined as any material that is discarded, abandoned, or is not of any direct economic value to its owner and thus constituting environmental liability. Solid, liquid and gaseous states are the major sub- classification of waste. Solid waste is non-liquid, non-soluble materials including municipal garbage and industrial wastes that contain complex and hazardous component. They include house, commercial, solid industrial, agricultural, mining residues construction and demolition (C&D) wastes, etc. Municipal Solid Waste (MSW) is part of the total solid waste stream, including commercial and residential wastes generated in municipal areas, either in solid or semi-solid form, excluding industrial hazardous wastes. Of these waste types, solid waste is one of the most critical from the management point of view.

One of the major problems facing urban communities today therefore, is the efficient and long term disposal of waste. Consequences of interaction of waste with the ecosystem include health hazards, viral, bacterial, and protozoan infections Berry (1974); infectious diarrhea, salmonellosis and shigellosis (Olayemi, 2004). Because leachate contains mixture of plastics and other synthetic fabrics, toxic fume (dioxine) usually accompany the option of burning (Agunwamba, 2000). Fat and oil components of waste may produce polycyclic aromatic hydrocarbons (Stevenson and Butler, 1969); these may be washed into the soil by rain thereby contaminating the surface and groundwater source. Orlov and Yerochicheva (1969) reported that interaction of toxic liquid waste with soils sesquioxides (Iron and Aluminium oxides) may weaken their strength and suitability as engineering construction materials. Recent study also revealed that leachate has significant adverse influence on the geotechnical properties of lateritic soils (Loizidou and Kapetanios, 1993; Tsai aand Vesilind, 1998; Sunil et al*.,* 2008; Wang and Shao, 2009; George and Benna, 2011). Because a leakage from a landfill liner can cause adverse and harmful effects on the environment, strict specifications are imposed on selection, design and construction of sanitary landfill.

Waste management methods such as burning, recycling, reduce, reuse, reduction, incineration, composting etc, have been practiced to curtail menace of environmental degradation from waste. Despite advancements in these modern technologies to increase employment of energy and materials recovery, landfills will still be necessary for disposal of a final and/or unusable waste. For example the data on waste disposal practice in developed and developing countries show that higher percentage of waste is land filled (Fig. 1). Thus, selection of quality materials usable as barrier infiltration of pollutants is paramount

1.1. Sanitary landfill

The purpose of a sanitary landfill is to isolate solid waste from the environment. This means that no harmful substances from the waste body could reach the environment in unacceptable quantities. The isolation of the waste material from the environment is achieved by providing an impermeable barrier all around the waste body. The barrier is partly constructed above the ground and below ground level (Fig. 2).

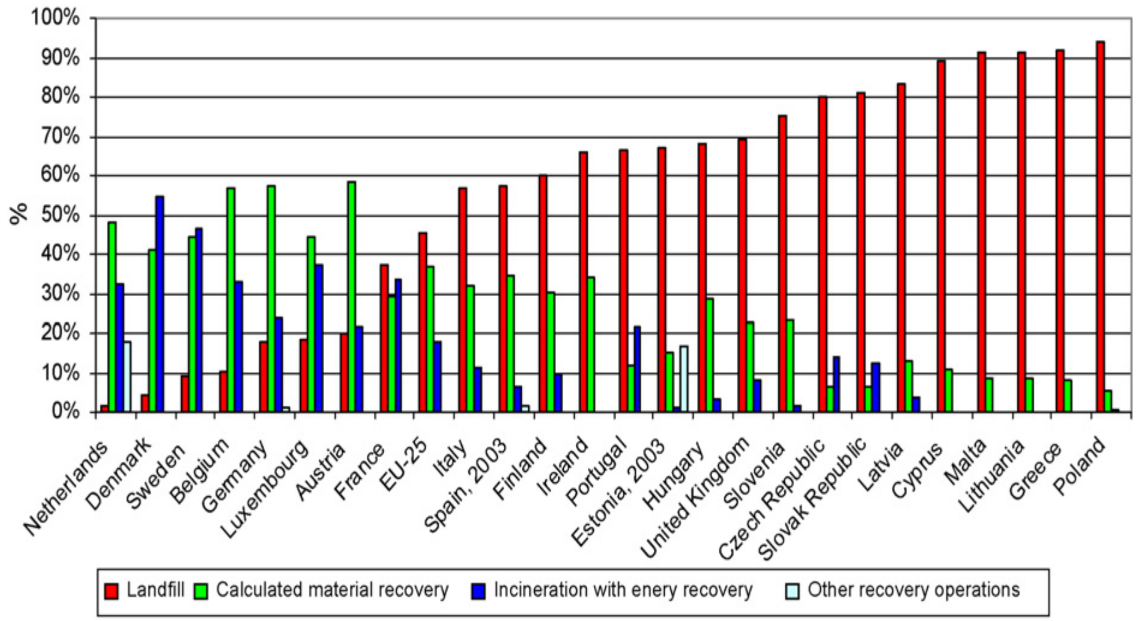

Figure 1. Use of landfilling, Incineration and Material recovery as treatment options in some countries in the world (Eurostat Structural Indicators on municipal waste generated, incinerated and landfilled, supplemented with national statistics 2007)

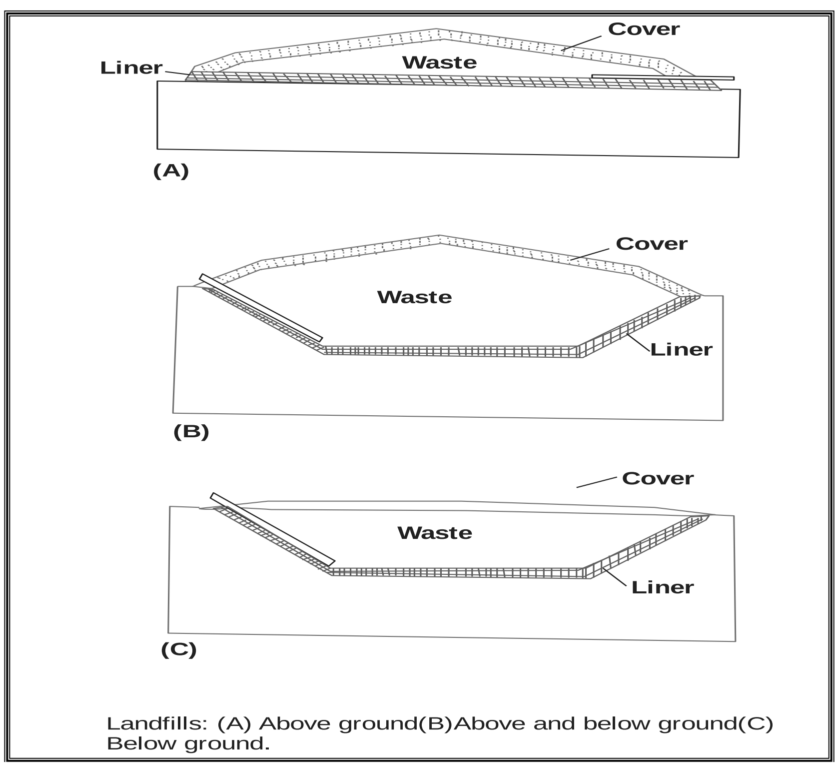

Figure 2. Types of Sanitary Landfills based on methods of emplacement (after Daniel, 1993)

1.2. Elements of lining system

1.2.1. Vegetation layer

The function of the restoration layer is to protect underlying layers (specially sealing layer) from frost, desiccation, root penetration, burrowing animals etc. This task of the restoration layer is achieved by the appropriate characteristics of the layer itself and by the existence of vegetation which should minimize erosion and reduce infiltration by evapo-transpiration.

1.2.2. Drainage layer

A drainage layer should be placed in order to drain the overlying restoration layer and to reduce the head of water on the sealing layer which minimizes infiltration into the landfill. Typically, small size coarse sand material is used.

1.2.3. Sealing layer

The sealing layer is the most critical component of a capping system. The sealing layer minimizes and/or prevents percolation of water through the capping system directly by impeding infiltration and indirectly by promoting storage or drainage of water in the overlying layers. Common materials usable as liner material are natural clay, Geomembrane and Geosynthetic clay

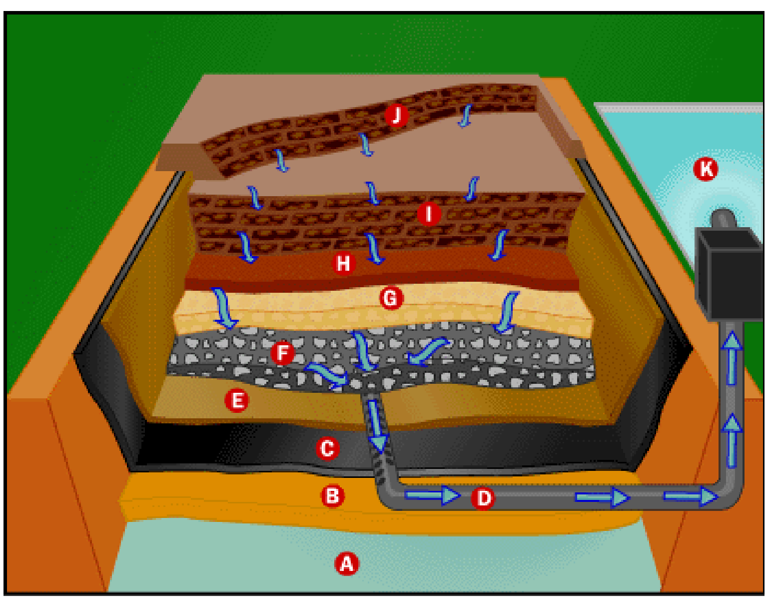

Figure 3. A complete illustrative model of lining system in an engineered landfill

2. Materials for mineral seal

2.1. Compacted cohesive soil liners

Natural lateritic and clayey soils are the most common compacted soil suitable as liner in sanitary landfills. Their suitability depend on several factors, but importantly on distribution of grains, type of clay mineral and permeability characteristics. Geographically, this type of soil are restricted to the tropic and subtropic areas of the world; defining the lateritic zones of the world (Fig. 4). Investigations of the properties of lateritic soil types from the southwestern region in the Nigeria segment of these zones have been documented (Ige 2007; Ige, 2010; Ige et al*.,* 2011). Other earthen materials that have been tested as usable liners in sanitary landfills include Fly ash, Paper Mill Sludge (El-Sohby et al*.,* 1993; Jones et al*.,* 1993; Zimmie et al*.,* 1993). Geotechnical criteria required for lateritic soil to be suitable as liner are compiled in Table 1. However, conditions for suitability vary from place to place due to peculiar factors such as climate, chemical composition etc.

2.2. Geomembranes

Geomembranes are relatively thin sheet of flexible thermoplastic or thermoset polymeric materials that area manufactured and prefabricated at a factory and transported to site for installation. It can be defined as a thin, flexible, continuous, fluid-impermeable synthetic or bitumenuous based product (Bishop and Carter, 1993). Geomembranes have been used extensively as effective lining system in landfill engineering as a barrier to liquid due to their inherent low permeability and ability to withstanding local differential settlement (Daniel, 1993).

Types of geomembranes used in landfill projects include High density polyethylene (HDPE), Liner-Low density polyethylene (LLDPE), Flexible Polypropylene (FPP), Polyvinyl Chloride Chlorosulphonated Polyethylene (CSPE)

2.3. Geosynthetic clay liners

A geosynthetic clay liner consists of a thin layer of clay (typically bentonite) sandwiched between two geotextiles or attached to a geomembrane. The primary purpose of the geosynthetic component(s) is to hold the bentonite together in a uniform layer and permit transportation and installation of the material without losing bentonite or altering the thickness of the bentonite (Daniel, 1993). The reason for the use of geosynthetic clay liners in capping systems is the existence of several deficiencies which make the long-term performance of a compacted clay liner questionable. These problems can be summarized as follows (Daniel, 1993), Difficulties in compaction on a soft foundation, tendency for desiccation and cracking without adequate protection, vulnerability to damage from freezing and compulsory protection from freezing by suitably thick layer of cover soil, differential settlement of underlying compressible waste which will cause cracking in compacted clay if tensile strains become excessive, compacted clay liners are difficult to repair if/when damaged.

Table 1. Required Geotechnical Parameters and Quality of Useable Liners in Sanitary Landfill (Compiled by Ige et al., 2011)

PARAMETERS	AUTHOR(S)	RECOMMENDATIONS
GRAIN SIZE ANALYSIS	Oeltzschner (1992)	Clay fraction <20%
	Bagchi (1994)	Largest Grain Size ≤63mm
	ONORMS 2074 (1990)	Silt/clay fraction ≥15%
	ONORMS 2074 (1990)	Largest grain size <25mm, %Gravel <30, % fine ≥30
	Daniel (1993b), Rowe et al. (1995)	
ATTERBERG CONSISTENCY LIMITS		LL ≥30%, IP≥15%
		LL ≥30%, IP≥10%
	Daniel (1993b); Rowe et al. (1995)	LL ≥30%, IP≥15%
		LL ≥25%, IP≥15%
	Seymour & Peacock (1994)	LL ≥30%, IP≥15%
	Oeltzschner (1992)	Inorganic Clay of low – medium plasticity(CL-CI) and Ac of <1.25
MOISTURE CONTENT- DENSITY RELATIONSHIPS	ÖNORMS 2074 (1990)	MDD ≥ 1.71t/m^3
	Kabir and Taha (2006)	MDD ≥ 1.74t/m^3
COEFFICIENT OF PERMEABILITY (*k*)		≤1x10^{-9}m/s
	Murphy and Garwell (1998)	≤1x10^{-9}m/s
	Mark (2002)	≤1x10^{-9}m/s
	Joyce (2003)	≤1x10^{-8}m/s
	Fred and Anne (2005)	≤1x10^{-9}m/s

SP= Standard Proctor LL= Liquid Limit MP= Modified Proctor IP= Index of Plasticity Ac=Activity of clay

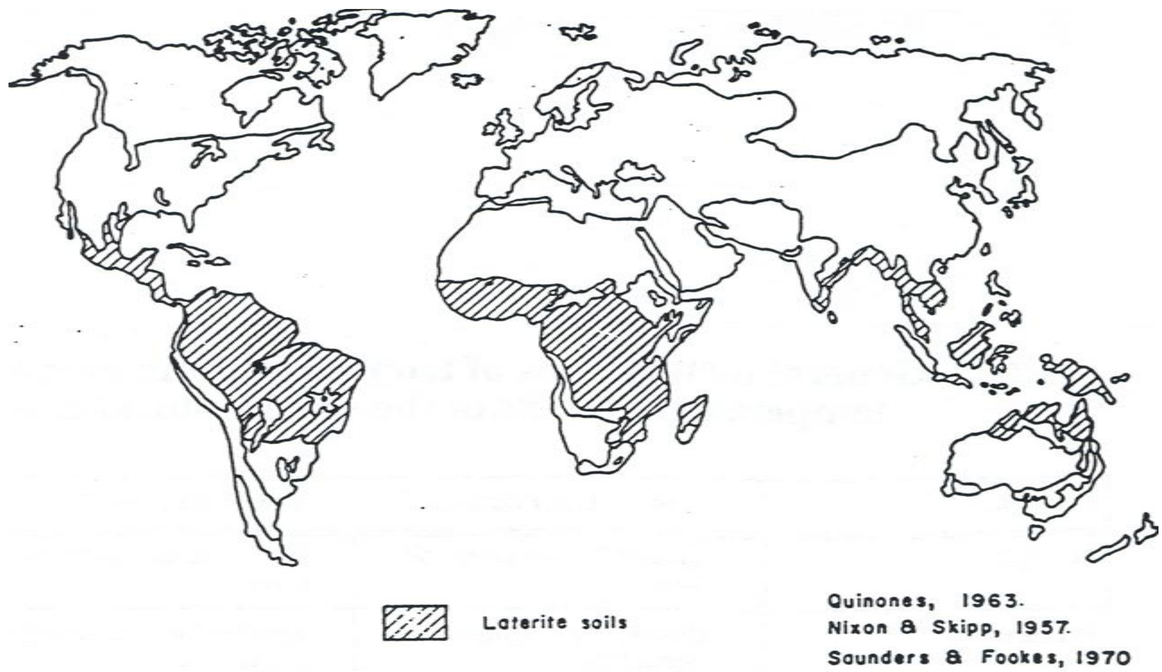

Figure 4. World Laterite soil zones

2.4. Soil-Bentonite mix

Bentonite has been used widely as a soil modifier by blending it with existing soils. Bentonite is a commercially available earthen product based in highly water-swelling clay minerals. Swelling soils are encountered in many localities around the world. Identification, mining, and marketing of soils high in water-swelling clay minerals locally in developing countries is highly desirable if it has not been already done. In areas where soils suitable for liner materials are not readily available, mixing with bentonite clay could enhance sealing characteristics in a cost-effective manner. At the same time, however, one has to recognize the relatively higher sensitivity of swelling clay minerals to different chemical constituents of the waste.

2.5. Fly ash as a liner

A large percent of the electric power generated in the world is produced from coal combustion. This process produces large quantities of coal ash per year. Fly ash, the lighter smaller particles carried in the flue gas, is frequently handled dry for disposal or utilization. This dry storage maintains the pozzolanic capabilities of the fly ash. Fly ash-stabilized soil may have potential for use as a liner material at fly ash and/or scrubber sludge landfill sites, nonhazardous waste lagoons, e.g., manure pits, wastewater treatment lagoons, and landfills, either alone or in combination with geomembranes.

The potential for each of these applications requires an understanding of the permeability of the potential barrier materials. This can be established by carrying out such test as classification, compaction, strength, permeability, cation exchange capacity. However, proper functioning of a liner system is critical to the total containment effectiveness of a landfill. Thus, individual compacted clay liners and geomembranes are no more commonly used. Instead composite geomembrane/clay liners are used. Composite liners may consist of a single or durable composite liner. In either case, the geomembrane is nearly always placed above the clay, although other arrangements are also possible.

3. Conclusion

Material for liner is the most critical component of the final cover. They must be selected in accordance with regulatory standards and economic constraints in order to prevent water infiltration into waste body, thus reducing the quantity of leachate in waste body. Site engineers use different type of materials such as natural, synthetic or waste materials as alternative solution, for the sealing layer. In planning for waste disposal operations in developing countries, geotechnical engineering approach should aim at minimum cost solutions by using unconventional materials like natural clay, discarded swelling materials, fly ash etc., where they are available.

Acknowledgements

The author is immensely grateful to the University of Ilorin administration for the award of Staff Development Grant that facilitated the compilation of this information.

References

Agunwamba, J.C. (2000), "Solid Waste Management in Nigeria: Problems and Issues", *Environmental Management,* Vol. 22, No 6, pp. 849-856.

Bagchi, A. (1994), "Design, Construction, and Monitoring of landfills". *2nd Edition, A Wiley-Interscience Publication*. U. S. A, 361 p.

Berry, B.J.L. (1974), Land use, Urban Form and Environmental Quality. *University of Chicago, Geography Department,* Issue No. 155.

Bishop, D.J and Carter., G. (1993), "Waste disposal by landfill – German landfill lining systems". *GREEN '93 – An international symposium on geotechnics related to the environment, Noembe. 20-22, Bolton, Balkema, Rotterdam.*

Daniel, D.E. (1991), "Compacted clay and geosynthetic clay liners". *Conference di Geotechnica di Torino, XV Ciclo, Torino*

Daniel, D.E. (1993), “Pollution prevention in landfills using engineered final covers”. *GREEN ’93 – An international symposium on geotechnics related to the environment,20-22nd November, Bolton, Balkema, Rotterdam.*

Daniel, D.E. and Benson, C.H. (1990), “Water content - density criteria for compacted soil liners”. *Journal of geotechnical engineering, A.S.C.E.,* vol. 116, pp. 12-16.

Shah, K.L. (2000), “Basics for Solid and Hazardous Waste Management Technology”. *Upper Saddle River: Prentice Hall.*

El-Sohby, M.A., Elleboudy, A.M. and El-Bakey, M.T. (1993), “Utilization of expansive soils for lining of waste disposal landfills”. *GREEN ’93 – An international symposium on Geotechnics related to the environment, held between November, 20-22nd in Bolton, Balkema, Rotterdam.*

Fred, L and Anne, J. (2005). “Flawed technology of subtitle D”. *Landfill Municipal Solid Waste. Available at h*ttp. www.gfredlee.com.64p (accessed 17 January 2013)

Ige, O.O. (2007), “Engineering Geological Assessment of some soils from southwestern Nigeria as mineral seal in Sanitary Landfills”. *Nigerian Journal of Pure and Applied Science*, *Faculty of Science, University of Ilorin, Ilorin, Nigeria* Vol. 22: pp. 2063-2068.

Ige, O.O. (2010), “Landfill site Selection for Municipal solid waste and Assessment of soils as mineral seals around Ilorin, Southwestern, Nigeria”. *A PhD Thesis submitted to the University of Ilorin, Nigeria.*

Ige, O.O; Ogunsanwo, O and Hilary, H.I. (2011), “Characterization of Terrain and Biotite Gneiss-Derived Lateritic soils of Ilorin, Nigeria, for use in Landfill Barriers”. *Global Journal of Geological Sciences.* Vol. 9, 1, pp. 1-9.

Jones, R.M., Murray, E.J., Rix, D.W. and Humphrey, R.D. (1993), “Selection of clays for use as landfill liners”. *GREEN ’93 – An international symposium on Geotechnics related on the environment, held between November, 20-22nd in Bolton, Balkema, Rotterdam.*

Joyce, M.P.E. (2003), “A study of the merit and effectiveness of alternate liner Systems at Illinois landfills”. *A research paper submitted in fulfillment of house resolution 715 State of Illinois* 92nd General Assembly. 46 p.

Kabir, M.H. and Taha, M.R. (2003), “Sedimentary residual soils as a Hydraulic barrier in waste containment systems”. *2nd International Conference on Advances in soft soil Engineering. Technology Putrajaya*, Malaysia. Pp.894-904.

Loizidou, M. and Kapetanios, E.G. (1993), “Effect of leachate from landfill on groundwater quality”, *The Science of the total Environment,* Vol. 128, pp. 69-81.

Mark, Y. (2002), “Geology and Geotechnical Investigation of the proposed Canterbury regional landfill”. *Kate Valley, North Canterbury Transwaste Canterbury Ltd.* 147 p.

Murphy, R. and Garwell, E.J. (1998), “Infiltration rate through landfill liners Florida centre for solid and hazardous waste management report. #97-11”, Available at *http:www.floridacentre.org/publications,* (accessed 22 December, 2012), 106p.

Oeltzschner, H. (1992), "Anforderung an die Geologic, Hydrogeologie und Geotechnik beim Bau von Deponie". *In: THORME-KOZMIENSKY K. J.(ed). Addichtung von Deponien und Atlasten. E. F. Verlag fur Energic und Umwelttechnik GmbH.* p: 53-82.

Olayemi, A.B. (2004), "Bacteriological water assessment of an urban city in Nigeria". *International Journal of Environmental Health.* Vol. 4, pp. 60-68.

Onorm, S. (1990), "Geotechnik in Deponiebau-Erdarbeiten. Osterrichisches Normungsinstitut", Wein.

Orlov, D.S. and Yeroshicheva, N.L. (1967), "Interaction of humic acids with the cations of some metals" . *Soviet Soil Science.* Vol. 12, 1799-1806.

Rowe, R.K., Quigley, R.M. and Booker, A.P. (1995), "Clayey barrier Systems for Waste Disposal facilities". *1st Edn. E and FN Spon,* New York, USA.

Seymour, K.J. and Peacock, A.J. (1994), "Quality Control of Clay Liners". *In: Christensen T. H. et al. (eds). Landfilling of Waste*: Barriers.E & EF Spon, London pp: 69-79.

Stevenson, F.J. and Butter, J.H. (1969), "Chemistry of Humic acids and Related Pigments". *In: G. Eglington and M.T.J Murphy (eds) Organic Geochemistry Methods and Results, Springer Verlag, Berlin.*

Sunil, B.M., Shihari, S. and Nayak, S. (2008), "Soil-Leachate Interaction and their Effects on Hydraulic Conductivity and Compaction Characteristics". *Conference Proceedings of the 12th International Association for Computer Methods and Advances in Geomechanics*. 1-6 October, 2008. Goa, India.

Tsai, T. and Vesilind, P.A. (1998), "A new landfill Liner to reduce groundwater contamination from heavy metals". *Journal of Environmental Engineering.* Vol. 124, 11, pp. 1061-1065.

Wang, Y. and Shao, M. (2009), "Infiltration Characteristics of Non-aqueous phase liquids in undisturbed loess soils. *"Journal of Environmental Sciences.* Vol. 21, pp.1424-1431.

Zimmie, T.F., Moo–Young, H. and LaPlante, K. (1993), "The use of waste paper sludge for landfill cover material". *GREEN '93 – An international symposium on Geotechnics related to the environment, held between November, 20-22nd in Bolton, Balkema, Rotterdam.*