A Review of Waste Management Techniques in parts of Niger Delta, Nigeria

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Abstract
Inadequate waste disposal techniques have created subtle and yet serious environmental pollution and ecological deterioration in Niger Delta, Nigeria. In recent years, there has been a phenomenal increase in the volume of wastes generated daily in the area. This is due to a number of reasons, including the increasing population growth rate, urbanization, industrialization and economic growth. The manner in which municipal and industrial wastes generated are disposed in the urban areas in Niger Delta, Nigeria is worrisome. The practice of dumping of wastes in abandoned burrow-pits and along river channels without any adequate safety devices results in soil and groundwater contamination through dumpsite leachate. The need to protect these natural resources from contaminant leads to the design of a sanitary landfill system. Pollution abatement, waste reduction, energy saving, health and economic benefits are some of the advantages of the newly designed sanitary landfill system. The public should be educated in the area of waste minimization techniques. The design is recommended for use in future construction of landfills in the area.

Keywords: Modern Sanitary Landfill, Niger Delta, Waste Generation and Management,

Introduction

Generation of wastes is a daily affair. The challenge of waste disposal has become one of the most serious environmental problems facing many cities in Nigeria especially the Niger Delta region due to the peculiarity of its shallow aquifers (unconfined, porous, permeable and shallow water table). Many urban areas of Nigeria lack effective waste management systems, which have resorted to the haphazard dumping, burning or burying of solid wastes. The challenge facing the global community today is how to develop a waste disposal system that is environmentally friendly (Olanrewaju and Ilemobade, 2009; Amadi, *et al*., 2012a).

Waste management is the collection, transport, processing and monitoring of waste materials. The management of wastes is aimed at reducing the harmful health and environmental impacts of solid, liquid and gaseous wastes through different techniques. Waste management practices in developing nations are influenced by customs, beliefs and level of education of the people and are partly the responsibility of local government authorities. Disposal of waste in a landfill involves burying the waste or burning it and this remains a common practice in most developing countries. Landfills are often established in abandoned quarry sites, mining sites, borrow-pits or erosion sites (Plate 1). This ancient, poorly designed and managed landfills can create a number of adverse environmental impacts such as generation of leachate (Plate 2), odour problems, eroding of surface vegetation and attraction of rodents. There has been an increasing rise in environmental pollution globally as a result of man's activities (domestic, industrial and agricultural), which includes: institutional wastes, street sweepings, commercial wastes, abandoned vehicles, as well as construction and demolition debris. The majority of substances composing municipal solid waste include paper, vegetable matter, plastics, metals, textiles, rubber and glass.

The practice of open dumpsites as a method of waste disposal in many developing countries like Nigeria is far from standard recommendation (Mull, 2005; Adewole, 2009). The conversion of burrow-pits used for road construction, erosion sites and river channels into dumpsites (Plates 1a&b) in most parts of the country, especially in the southern coastal region, with shallow groundwater table and largely unconfined, highly porous and permeable aquifer system is of great concern to environmentalists and hydrogeologists as health safety of any community depends on its environmental sanitation level. The use of unlined pit-latrine and soak-away pits (Plate 2a&b) in areas with shallow groundwater system is disturbing and increases the vulnerability of the aquifer system to contamination. In most developing countries, there are still millions of people today that lack adequate hygienic and acceptable domestic waste disposal and treatment methods (Hassen, *et al*., 2001; Amadi *et al*., 2012b). This situation calls for urgent and practical solutions, not only from environmental and health authorities but also from the individuals concerned. However, due to economic reasons and lack of information on sanitary health protection, improvements are not forthcoming and the situations remain unchanged, hence the need for a paradigm shift in the way and manner wastes are generated and managed.

Proper waste management and efficient system of solid and fluid disposal techniques are lacking in most developing countries. Waste disposal techniques have created subtle and yet serious environmental pollution and ecological deterioration in many developing countries such as Nigeria. The manner in which municipal and industrial wastes generated are disposed in most urban areas in Nigeria is worrisome. The use of inadequate disposal system and lack of consideration of the topography, geology and hydrogeology are the causes of pollution arising from waste disposal in many developing countries (Amadi *et al.,* 2010; Amadi *et al.,* 2012a).

In Nigeria, open-dump is the most available option for waste disposal in the state capitals as sanitary landfill is rare and unpopular (Elaigwu, *et al*., 2007). Complex geochemical processes control the enrichment of heavy metals in groundwater (Adewumi, 2001; Amadi, 2010). The chemistry of groundwater depends not only on natural factors such as the lithology of the aquifer, the quality of recharge waters and the types of interaction between water and aquifer, but also on human activities, which can alter these fragile groundwater system, either by polluting it or by changing the hydrological cycle (Landerth *et al*., 1996; Fleming, 2001; Prakash *et al*., 2007).

The application of conventional refuse and sewage treatment systems in use in industrialized nations may not be realistic for developing countries due to their high cost of construction and maintenance. Hence, the need to develop a practical home-based waste disposal and treatment system that could be easily integrated into the climatic, geological and socio-cultural conditions existing in these nations is the focus of the paper. This method of waste disposal is environmentally friendly, as well as relatively low system capital and operating cost. It has a simple design that is a function of the local geology and available materials and when adopted and practiced will certainly protect the groundwater from contamination.

Municipal wastes and their disposal mechanisms are a great concern in developing countries across the world, as poverty, over-population and rural-urban drift due to urbanization in addition to non-enforcement of existing sanitary laws on offenders as well as poor-funding by governments of these countries are responsible for the inefficient management of wastes (UNEP 2002, Pakistan Environmental Protection Agency, 2005). Domestic and industrial wastes contain a number of harmful microorganisms and trace elements and their presence in groundwater can result in an outbreak of water-borne diseases such as typhoid, diarrhea, hepatitis and gastro-intestinal infections (Amadi, 2009; Adewole, 2009). Most of these diseases are unfortunately still rampant in most developing countries today and are known to be the causes of many deaths, especially within the vulnerable group (children and women). Poor waste management in these countries favours the outbreaks of water-borne diseases. Therefore, improvement on existing waste disposal methods (open dumps) and introduction of new techniques that quarantee high level of health safety as well as groundwater protection as advocated in this research should be encouraged by concerned stakeholders.

In most cities in developing countries, it is common to see huge heaps of domestic and allied wastes such as garbage, plant leaves, damaged agricultural produce, spoiled food materials, pieces of paper, polythene bags, old cloths, wood, abandoned metals, vehicle scraps, used tires, plastics, glass, dust, damaged electronics, industrial wastes, animal wastes, hospital wastes, sanitary pads, pampers, construction materials and demolition debris resulting from over-population, urbanization and industrialization (USEPA, 2003). When these wastes are improperly disposed, which is usually the case in major cities in Nigeria, they constitute threats to air, land, water and man. During decomposition, it produces bad smell and serves as feeding ground for pests that spread diseases, blockage to drainage channels and creating a myriad of health-related and environmental problems. Leachates from the decomposition of these wastes at dumpsites are potential sources of soil and water pollution. Therefore, the need for an efficient and cost-effective waste management technique that will guarantee protection to the soil, surface and groundwater systems, cannot be ignored. Proper waste management and effective waste disposal system are required in southern Nigeria considering its salient and peculiar geology and hydrogeology.

Geology and Hydrogeology of Southern Nigeria

The Niger Delta Basin is underlain by the coastal plain sands and alluvium (Fig.1). The formation is made up of loose, fine to coarse grained sands with minor clay intercalations (Onyeagocha, 1980). It consists of water-bearing, porous and highly permeable continental sands. Records from drilled boreholes indicate shallow groundwater table (xx – yy m) while pumping test analyses show high hydraulic characteristics in terms of yield, transmissivity and storativity. For any sanitary landfill to be effective and efficient, the climate, topography, geology and hydrogeology of the area must be recognized and accounted for by the design. The knowledge of the local geology where sanitary landfill is to be constructed is important, because it is what will determine the quality and quantity of construction materials to be used as well as the overhead cost of the entire project and therefore it should not be ignored (Amadi, 2010).

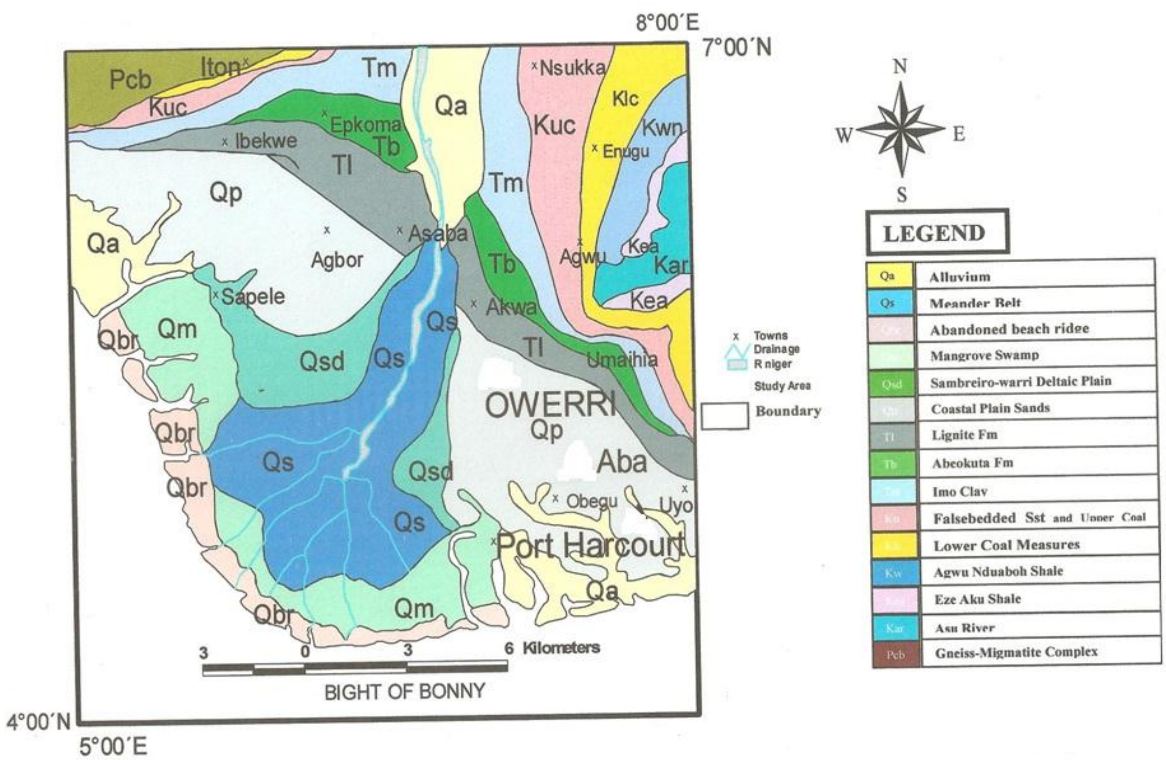

Fig.1: Geological map of the study area (Modified from Etu–Efeotor and Akpokodje, 1990)

Plate 1(a&b): Conversion of gully erosion site to a dumpsite in the study area

Plate 2(a&b): Discharge of leachate from unlined pit-latrine to the land surface

Methods of Disposal and Waste Management Concept

Waste management techniques involve minimization, source reduction, recycling, reuse and safe disposal of non-degradable materials.

Waste minimization

An important method of waste management is the prevention of waste material being created, also known as waste reduction. Methods of avoidance include reuse of second-hand products, repairing broken items instead of buying new, designing products to be refillable, encouraging consumers to avoid using disposable products, packaging and designing products that use less material. Waste hierarchy refers to the '3 Rs': reduce, reuse and recycle, which classify waste management strategies according to their desirability in terms of waste minimization. It is aimed at extracting the maximum benefits from products and to generate the minimum amount of waste as illustrated in the pyramid of waste hierarchy (Fig.2).

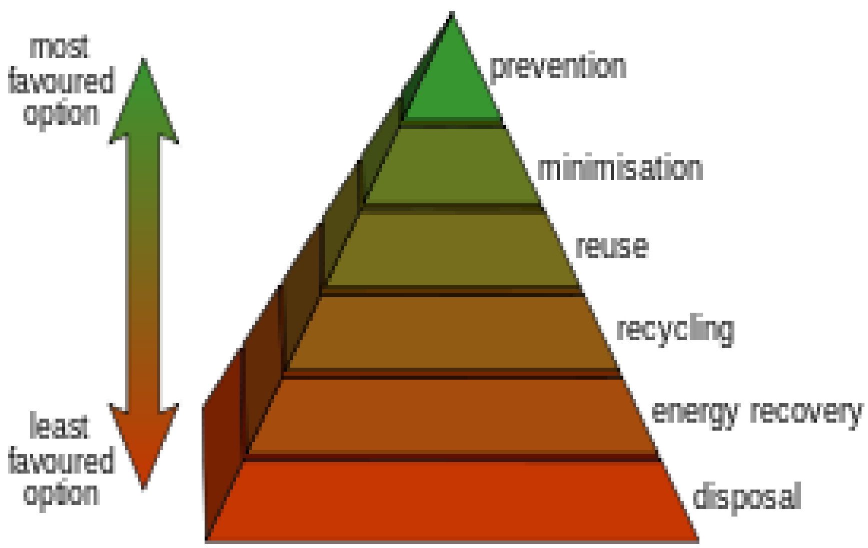

Fig. 2: Diagram of the waste hierarchy

Source reduction

This approach is unique because it prevents huge generation of solid wastes and provides for resource conservation. It is also more economical, environmentally safe and legally sound. Source reduction involves modifying a process, by substituting easily biodegradable materials for those that are resistant to degradation or replacing products that generate large amount of waste with those that do not.

Incineration

Incineration is a disposal method in which solid organic wastes are subjected to combustion in order to convert them into residue and gaseous products. This method is useful for refuse disposal and removal of solid residue from waste water. This process attempts to reduce the volume of the solids to between 25% and 30% of the original volume. Incineration and other high temperature waste treatment system converts waste materials into heat, gas, steam and ash. It can be carried on small scale by individuals and on a large scale by industries and is a suitable method of disposal of all classes of wastes. Waste collection methods vary widely among different countries and regions. The plastic waste bin (Plate 3) is advocated for temporal waste collection and should be made available in homes and offices. The wastes in the bin are later transferred to trash van for onward transportation into the sanitary landfills.

Plate 3: A typical waste collection bin

Recycling

Recycling is the recovery of materials for melting, re-pulping and reincorporating them as raw materials. It is technically feasible to recycle a large amount of materials, such as plastics, wood, metals, glass, textiles, paper, cardboard, rubber, ceramics, and leather. Besides technical feasibility and know-how, demand determines the types and amounts of materials that are recycled in a particular region. Recycling renders social, economic, and environmental benefits. It provides income to the scavengers who recover recyclable materials. Factories that consume recyclable materials can be built for a fraction of the cost of building plants that consume virgin materials. Organo-mineral fertilizer, high and low density polyethylene bags, egg crates, tissue paper, note books and business cards are some of the products of waste recycling. It saves energy, water, and generates less pollution than obtaining fresh raw materials, which translates into lower operating costs. It also reduces the amount of wastes that need to be collected, transported and disposed of, and extends the life of disposal facilities, which saves money to the municipalities. Recycling results in a more competitive economy and a cleaner environment. This contributes to a more sustainable development.

Reuse

The act of recovery or reuse is a norm in developing countries and it involves cleaning, repairing and refurbishing of abandoned items in order to use it again. Re-using materials and products reduces pollution, saves energy and conserves water.

Movement of leachate/contaminant in the subsurface

Leachate (contaminant) from open dumpsites migrates downward under the force of gravity. This movement depends on the viscosity of the leachate, quantity of leachate, permeability of the soil/rock and presence of fracture within the rock. Table 1 illustrates the permeability coefficient values for some types of soils and rocks. During the mobility through the unsaturated zone as in the case of the study area, there is absorption and reaction between the soil and the rock matrix tending to immobilize and attenuate the leachate. If the water table is far enough below the ground surface, the leachate may be immobilized in the unsaturated zone before it reaches the water table (Oteri, 1985). Leachate that are immobilized in the unsaturated zone may still contaminate the groundwater as a result of rainwater infiltrating through the contaminated soil, dissolving and leaching soluble components to pollute the groundwater. In case of shallow water table aquifers, like in the study area, where the leachate is immobilized in the unsaturated zone, it would still reach the water table. The pollution plume of leachate will move in the direction of groundwater flow in the aquifer within the pore spaces of soil and sediments.

Most communities in developing countries rely on groundwater heavily for potable, industrial and agricultural supplies. However, the suitability and sustainability of this resource is under threat in areas where there is unsanitary landfills and unlined pit-latrines. Due to groundwater contamination from dumpsite leachate, drinking water becomes unpalatable and even harmful when it is in contact with leachate from dumpsites.

Table 1: Summaries of permeability values for some soils and rocks
(After Lawrence *et al*., 2001)

Lithology	**Range of likely permeability (m/d)**
Silt	0.01 – 0.1
Fine, silty sand	0.1 – 10
Weathered Basement (not fractured)	0.01 – 10
Medium sand	10 – 100
Gravel	100 – 1000
Fracture rocks	Difficult to generate, velocity of tens or hundreds of m/d possible

(m/d= metre/day)

Alternative design for a modern sanitary landfill in developing economies

The design of a modern sanitary landfill should incorporate leachate collection chambers made of geomaterials such as clay liners or geotextiles material (Amadi, *et al*., 2012b). Deposited waste should be compacted to enhance its density and stability and covered to prevent the activities of flies and rodents. Gas extraction systems are installed to extract the landfill gas which can be used to generate electricity. This technique will ensure that the soil and groundwater is not polluted via leachate from dumpsites. The nature of the geology of the area and the need to protect groundwater from contamination through various human activities in the area will necessitate the choice of the designed landfill types. Phytoremediation is defined as the use of living plants to remediate contaminated soil or water through removal, degradation or containment of the pollutants. Plants, like indian mustard, are used to extract heavy metals from contaminated sites. Figures 2, 3 and 4 are proposed for high vulnerability area, moderate (medium) vulnerability area and low vulnerability area as it corresponds to unconfined, semi-confined and confined aquiferous zones respectively.

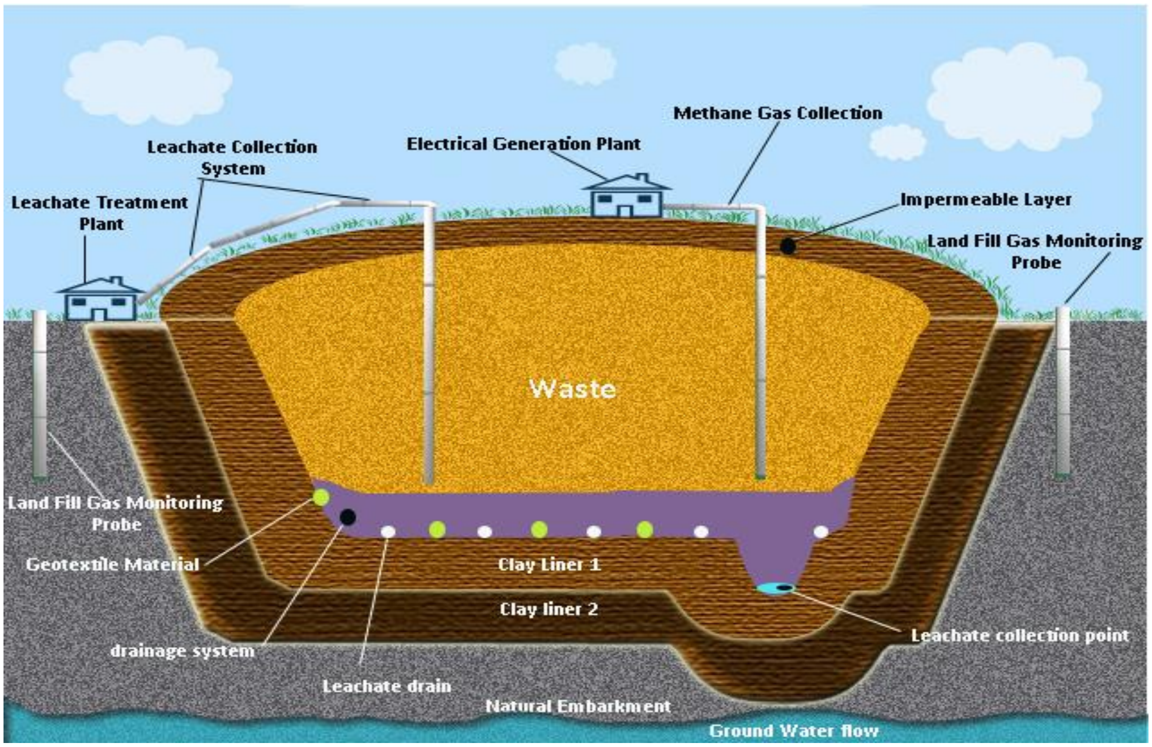

Fig.2: A modern sanitary landfill with two clay liners for high vulnerability area (Source: Amadi, *et al*., 2012a)

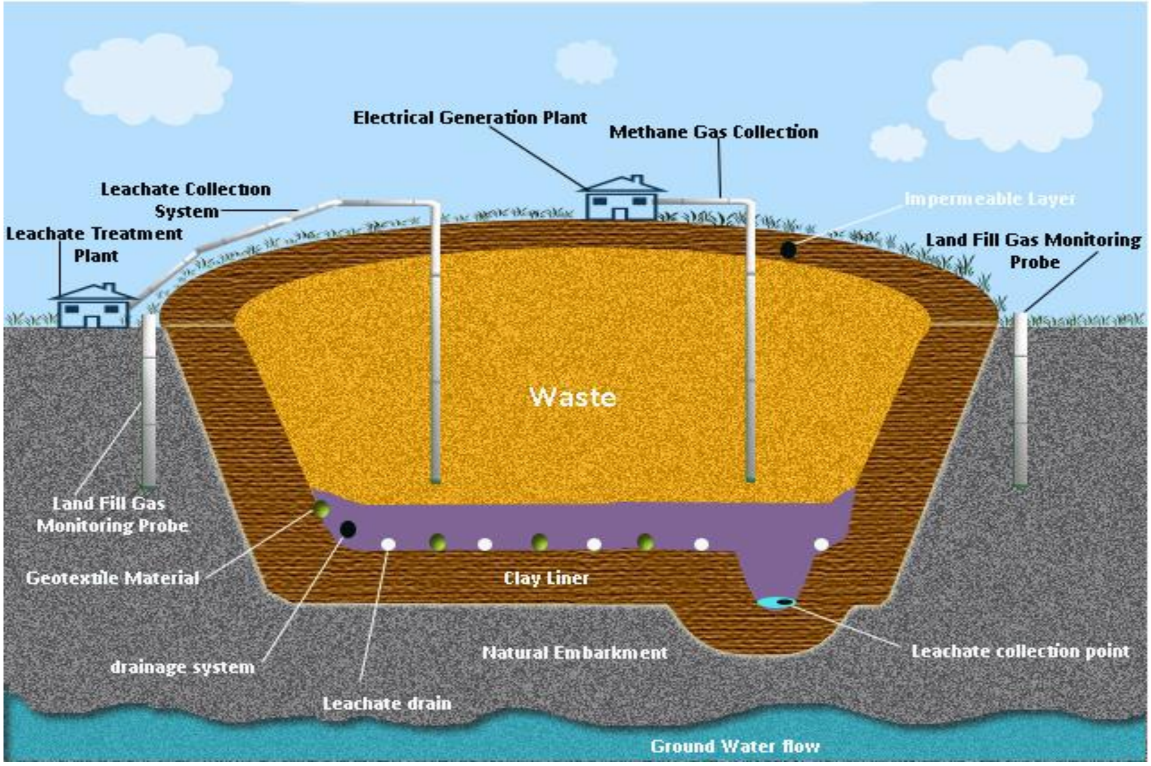

Fig. 3: A modern sanitary landfill with one clay liner for moderate vulnerability area (Source: Amadi, *et al*., 2012a)

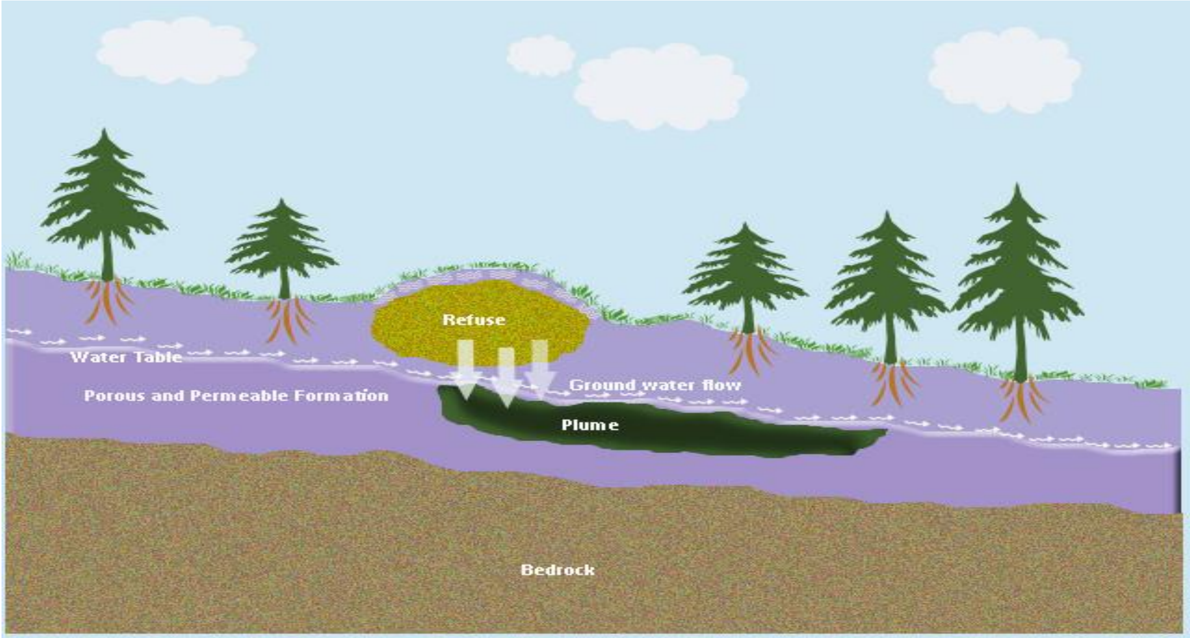

Fig.4: Phytoremediation technique to control leachate from dumpsite low vulnerability Area (Source: Amadi, 2011)

Conclusion and Recommendations

Leachate from inadequately designed dumpsites constitutes environmental and health hazards. The need to incorporate safety devices in the construction of sanitary landfills should be seen as an investment with significant returns in environment and health. The proposed sanitary landfill design methods will to a substantial degree prevent soil and groundwater contamination in the area. Workshops and seminars should be organized on regular bases and the dangers and health impacts of indiscriminate dumping of refuse on the surroundings should be highlighted. Government agencies like the Federal Ministries of Environment and Water Resources should be empowered to prosecute offenders. Necessary legislation should be enacted to ensure that future landfills in the area meet the minimum standards for soil and groundwater protection before construction. Site investigation should be carried out on the proposed landfill site by a COMEG registered geoscientist.

The public should be educated regarding waste minimization techniques at home and places of work. The success of waste minimization relies largely on education, increase in public awareness and people's willingness to change their wasteful habits. For these reasons, waste education must be implemented first. In addition, source separation activities should be implemented at household level in other to minimize the cost of separation at the recycling plants and to enhance the quantity and quality of the recyclables. Scavenging should be properly coordinated for the purpose of deriving maximum economic benefits from such activities and also for the health and safety of those involved.

Reference

Adefemi, P., (1980). Situation report on solid waste disposal in Lagos State. *Report presented at the refresher course in solid waste management in urban area. The Training Centre, Yaba, Lagos.*

Adewole, A.T., (2009). Waste management towards sustainable development in Nigeria: A case study of Lagos State. *Int. NGO J.,* 4(4), 173 – 179.

Adewumi, I., (2001). Waste management in Nigeria: Issues and Prospects. *A paper presented at the 38th National Conference/Scientific Workshop of the Professional Association of Environmental Health Officers of Nigeria*

Amadi, A.N., Olasehinde, P.I., Okosun, E.A., Okoye, N.O., Okunlola, I.A., Alkali, Y.B. & Dan-Hassan, M. A., (2012a). Comparative study on the impact of Avu and Ihie dumpsites on soil quality in Southeastern Nigeria. *American Journal of Chemistry,* 2(1), 17 – 23.

Amadi, A.N., Nwankwoala, H.O., Olasehinde, P.I., Okoye, N.O., Okunlola, I.A. & Alkali, Y.B., (2012b). Investigation of aquifer quality in Bonny Island, Eastern Niger Delta, Nigeria using geophysical and geochemical techniques. *Journal of Emerging Trends in Engineering and Apllied Sciences,* 3(1), 180 – 184.

Amadi, A.N., (2011). Assessing the Effects of Aladimma Dumpsite on Soil and Groundwater Using Water Quality Index and Factor Analysis. *Australian Journal of Basic and Applied Sciences*, 5(11), 763 – 770.

Amadi, A.N., Yisa, J., Okoye, N.O. & Okunlola, I.A., (2010). Multivariate statistical evaluation of the hydrochemical facies in Aba, Southeastern Nigeria. Science Focus: *International Journal of Biological and Physical Sciences,* 15(3), 326 – 337.

Amadi, A.N., (2010). Industrialization and groundwater quality in Eleme, Rivers State. *Katsina Journal of Pure and Applied sciences,* 2(1 & 2), 171 – 177.

Amadi, A.N., (2009). Evaluation of Surface and Groundwater Quality in Owerri Metropolis, Southeastern Nigeria. *International Journal of Chemical Sciences,* 2(2), 212 – 219.

Elaigwu, S.E., Ajibola, V.O. & Folaranmi, F.M., (2007). Studies on the impact of municipal waste dumps on surrounding soil and air quality of two cities in Northern Nigeria. *Journal of Applied Sciences*, 7(3), 421 – 425.

Etu–Efeotor, J.O. & Akpokodje, G.E (1990). Aquifer Systems of the Niger Delta. *Journal of Mining and Geology*, 26(2), 264 – 266.

Fleming, G., (2001). *Municipal solid waste composting facility operation reference guide and handbook*. 23 – 45.

Hassen, A., Belguith, K., Jedidi, N., Cherif, A., Cherif, M. & boudabous, A., (2001). Microbial characterization during composting of municipal solid waste. *Bioresources Technology Journal*, 80, 217 – 225.

Landerth, R.E. & Rebers, P.A., (1996). *Municipal solid wastes: Problems and solutions*. Lewis Publishers, 83 – 98.

Lawrence, A.R., MacDonald, D.M.J., Haward, A.G., Barret, M.H., Pesley, S., Ahmed, K.M. & Nalubega, M., (2001). *Guidelines for assessing the risk to groundwater from on-site sanitation.* Published by British Geological Survey, 24.

Mull, E.J., (2005). Approaches toward sustainable urban solid waste management: Sahakaranagar Layout, Unpublished M.Sc. thesis, *Int. Environ. Sci., Lund University, Lund, Sweden.*

Olanrewaju, O.O. & Ilemobade, A.A., (2009). Waste to Wealth: A Case Study of the Ondo State Integrated Wastes Recycling and Treatment Project, Nigeria. *European Journal of Social Sciences,* 8(1), 7-16.

Onyeagocha, A.C. (1980). Petrography and depositional environment of the Benin Formation, Nigeria. *Journal of Mining and Geology*, 17, 147-151.

Oteri, A.U., (1985). *Groundwater pollution monitoring in environmental investigation. In the petroleum industry and the Nigeria Environment.* A. Thomopulus (Editor). Published by the Nigerian National Petroleum Cooperation., 257 – 264.

Pakistan Environmental Protection Agency, (2005). Guideline for solid waste management. http://www.who.or.id/eng/content/aceh/wsh/books/es/ESO7CD.pdf, retrieved on 19th March, 2012.

Prakash, U.H.B., Bhargavi, M.V., Parama, V.R.R. & Preethu, D.C., (2007). Bioremedial recycling of solid waste. *Proceeding of the International Conference on Sustainable Soild Waste Management*, September 5 – 7, Chennai, India, 289 – 295.

USEPA (Environmental Protection Agency, 2003). US National Recommended Water Quality Creteria: 2003. Office of Water, *Office of Science and Technology, Washington, DC*

UNEP, (2002). Depleted Uranium in Kosovo. Post Conflict Environmental Assessment. *United nations Environmental Programme*, Geneva, CH.