Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 3 Issue 9, September - 2017

Design Of Engineered Sanitary Landfill For Efficient Solid Waste Management In Ado – Ekiti, South-Western Nigeria

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***Abstract*—One of the largest environmental and public health issues that Nigeria is facing today is inadequate facilities for management of solid wastes. Design of sanitary land fill was done with major emphases on determination of the lifespan/target year and location of a suitable site. In this study a sanitary landfill system of depth 3.6 m, width 30.3m and length 72.8 m was designed and a model of it fabricated. The design of sanitary land fill entails the determination of the lifespan, location of a suitable site and carrying out financial analysis and determining the construction schedule of the landfill. Analysis of results obtained indicated that decomposable wastes (55.516%) are more generated than non-decomposable waste (44.484%) especially in Ado Ekiti. It is therefore recommended that government should take the management of waste serious because it can serve as a source of income.**

Keywords —Environmental; Sanitary; Landfill; Management; Design

1.0 INTRODUCTION

As a result of industrial revolution and increasing population, issues of environmental pollution and climate changes resulting from improper waste disposal has occupied the front burner in recent times. However, several attempts have been made over the years to ensure solid waste disposal ranging from dumping to burning of waste and landfilling with attendant contamination of the environment with harmful pollutants. As a result of industrial revolution and increasing population, issues of environmental pollution and climate changes resulting from improper waste disposal has occupied the front burner in recent times.

According to Adejobi and Olorunmbe (2012) as cited by Amuda *et al.*, (2014), the volume of waste generated in any city is often a reflection of the intensity of human activities such as population growth, urbanization and social development, resources exploitation and unchecked technological advancement. The environment and health conditions are hampered through the pollution emanating from improper solid waste disposal; hence there is need for the design of an engineered sanitary landfill for waste management in order to check the effect of improper waste disposal.

Unfortunately, many people in African countries including Nigeria, until recently, regard the concern for effective strategies for managing urban solid waste as a less important issue which may distract attention from the most urgent and serious problem of achieving a fast rate of economic growth. This attitude stems in part from the belief that environmental degradation with urban solid waste generation is an inevitable price of development (Salau, 1992; Chukwu, 2010 as cited by Uwadiegwu and Chukwu 2013). According to Tobore (2014), contributory factors to the challenge of ineffective solid waste management include inadequate regulatory framework that has manifested in lack of interest of private sector investment in service delivery (infrastructure); uncoordinated institutional functions; low political will, low capacity to discharges duties, poor data information for planning, wrong attitude of waste generator amongst others. Yet on the increase is the demand for good waste management service for public health and environmental protection.

1.1 Background to the Study

In particular low and middle income countries are still almost depending on landfilling or dumping of waste, since it is in particular the dumping of waste represents by far the cheapest method of waste disposal. However, landfilling of waste in many countries is still associated with severe negative impacts on the environment (e.g., groundwater and surface water pollution, greenhouse gas emissions) and the human health (e.g., landfill fires, landslides). In order to avoid or minimize negative impacts associated with the operation of landfills numerous guidelines for landfill operation and management have been prepared by governmental authorities and/or international agencies during the last decades.

1.2 Aim and Objectives of the study

The aim of this project is to design an engineered sanitary landfill for effective solid waste management. The objectives of this work are to:

i. assess the existing method of waste disposal in Ado Ekiti;
ii. design an engineered sanitary land fill; and
iii. make recommendations for effective solid waste management.

1.3 Statement of Problem

Solid waste disposal in Ado-Ekiti has one of the most intractable environmental problems. It has been observed that in many streets in Ado-Ekiti, the volume of solid wastes has overwhelmed urban administrators' capacity to plan for their collection and disposal. Thus, it is not uncommon to find streets and roads practically blocked by solid wastes.

1.4 Justification

As a result of industrial growth and increasing population, issues of environmental pollution and climate changes resulting from improper waste disposal, has occupied the front burner in recent times. Waste management, being one of the most important aspects of urban development, is gaining importance among developing nations. Landfills, which were initiated for hazardous waste management and subsequently transformed into sanitary landfills, have been the most widely adapted practice for municipal solid waste management worldwide. However, the conventional design of landfills not only fails to fulfil the needs of waste management but also fails to target optimal resource recovery and energy generation. Modern landfills are well-engineered facilities that are located, designed, operated, and monitored to ensure compliance with federal regulations. Solid waste landfills must be designed to protect the environment from contaminants which may be present in the solid waste stream. The landfill siting plan prevents the siting of landfills in environmentally-sensitive areas as well as on-site environmental monitoring systems which monitor for any sign of groundwater contamination and for landfill gas which provides additional safeguards. In addition, potentially harmful landfill gas emissions can be into energy thus converting waste to wealth.

1.5 Contribution to Knowledge

The work is expected to contribute to knowledge as follows;

i. Provision of design data base for sanitary land filling;
ii. Sensitization of host communities about dangers of improper waste disposal;
iii. Improvement of urban settling and protection of environment against pollutants emanating from improper waste disposal.
iv. Development of an engineered sanitary land filling system for optimal resource recovery and energy generation

2.0 LITERATURE REVIEW

Solid waste management (SWM) can be defined as the systematic interaction between various activities of waste generation, storage, collection, transfer and transport, intermediate treatment and final disposal. Newer concepts such as resource recovery, volume reductions, solid wastes stabilization or sanitation have been incorporated in the SWM processes. Although more advanced and sophisticated intermediate treatment methods have been developed, the sanitary landfilling method is still considered to be one of the most important and ideal final disposal process. The primary aim of ideal final disposal method is to adopt the sanitary and environmental friendly landfilling method. Other advanced concept of technology may also be integrated, such as effective post closure utilization, adoption of resource recovery and recycling philosophies, etc. For effective post closure utilization of the landfill site, it is essential to adopt the more advanced landfill management methods with semi-aerobic structure and equipped with higher level treatment facilities so that earlier stabilization of wastes may be achieved. Final disposal sites such as sanitary landfills must be utilized with consideration towards a sustainable environment and with regards to effective utilization of available resources. In providing such landfills, the use of recycled construction material such as those reclaimed from construction and demolition wastes like concrete debris or spent activated carbon, or biomass material should be encouraged.

Table 2.2- Average Annual Composition of MSW in a West African City (Generated and Disposed)

CATEGORY	**MILLIONS OF TONS**	**%**
Paper	37.2	29.2
Glass	13.3	10.4
Ferrous	8.8	6.9
Aluminium	0.9	0.7
Other Nonferrous	0.4	0.3
Plastics	6.4	5.0
Rubber & Leather	2.6	2.0
Textiles	2.1	1.6
Wood	4.9	3.8
Food Waste	22.8	20.4
Miscellaneous	1.9	1.5
TOTAL	**127.3**	**100.0**

	MILLIONS OF TONS	**%**
	44.9	35.3
	13.5	10.6
	8.8	6.9

2.2 Sanitary Landfill

Sanitary landfills are sites where waste is isolated from the environment until it is safe (Maggie, 1999). It is an option considered when it has completely degraded biologically, chemically and physically. In high-income countries, the level of isolation achieved may be high. However, such an expensive high level of isolation may not be technically necessary to protect public health. The ways of doing this should be adapted to local conditions. The immediate goal is to meet, to the best extent possible, the four stated basic sanitary landfill conditions, with a longer term goal to meet them eventually in full. Small incremental improvements in landfill design and operation over several years are more likely to succeed than attempts to make a single, large leap in engineering expectations.

Large landfills will require more investment to improve standards than smaller sites. However, the unit cost of these improvements (measured per tonne of waste landfilled or per head of population served) will decrease with increasing site size. There are financial and other benefits to sites with long operating lifetimes (ten years or more). Large regional sites serving two or more cities could be economically beneficial, providing waste transport costs are not too high.

2.1 Basic requirements for Sanitary Land fill

According to Maggie, (1999) as a minimum, four basic conditions should be met by any site design and operation before it can be regarded as a sanitary landfill, they are;

i. Full or partial hydrogeological isolation

ii. Formal engineering preparations

iii. Permanent control

iv. Planned waste emplacement and covering

2.1.1 Full or partial hydrogeological isolation

If a site cannot be located on land which naturally contains leachate security, additional lining materials should be brought to the site to reduce leakage from the base of the site (leachate) and help reduce contamination of groundwater and surrounding soil. If a liner - soil or synthetic - is provided without a system of leachate collection, all leachate will eventually reach the surrounding environment. Leachate collection and treatment must be stressed as a basic requirement. Figure 1 indicates Bio-reactor of leachate.

Figure 1: Anaerobic Bioreactor of Leachate

2.2 Waste Generation

The degradable wastes are wastes that can be transformed either by chemical or biological processes, i.e. by corrosion or by decomposition. Such waste can be sub-divided into biodegradable and non-biodegradable waste.

i. Biodegradable Waste

Biodegradable solid waste includes all organic matters such as meat, vegetables and plants wastes that can be decomposed by biological digestion and fermentation. The decomposition process, with the aide of micro-organisms, breakdown the higher molecular compounds like carbohydrates and protein into lower molecular compounds such as sugar, organic acids, alcohols, etc, which will then be fermented to form carbon dioxide, methane, inorganic salts and water. The decomposition process results in the volume reduction and achieves stabilization of the waste. The rate of decomposition depends mainly on the type of waste and the condition of the environment. Soft less fibrous waste such as kitchen waste will decompose faster than fibrous waste such as wood or paper. Wet and warm environment will also hasten the decomposition process by promoting bacterial growth.

ii. Non-biodegradable Waste

The non-biodegradable waste can also be considered as chemical-degradable waste, i.e. waste that can degrade by undergoing the processes of corrosion, ionic exchanges and liquefaction, due to chemical reactions and oxidations. Such matter includes all types of metals and some inorganic salts. The metals coming in contact with the water or acid present in the waste layers will oxidized to form rust or other forms of metallic oxides, which will eventually breakdown further to the ionic compound, and react with other chemicals to form gasses and salts. The combustion process, i.e. by incineration, paralysis, gasification etc. is also form of chemical transformation processes.

Table 1: Waste Generation and Composition

City	Population	Tonnage/month	Density (kg/m^3)	Kg/Capital/Day
Lagos	8,029,200	255,556	294	0.63
Kano	3,2228,700	156,676	290	0.56
Ibadan	307,840	135,391	330	0.51
Kaduna	1,458,900	114,433	320	0.58
Port Harcourt	1,053,900	117.825	300	0.60
Makurdi	249,000	24,242	340	0.48
Onitsha	509,500	84,137	310	0.53
Nsukka	100,700	12,000	370	0.44
Abuja	159,900	14,785	280	0.66

Source (Ogwueleke 2009; Tubore 2014)

Presently, the rate of waste generation in Lagos (with estimated population over 10 million 2012) is 9, 000 tonnes/day (Lagos State Waste Management Authority, LAWMA) while in Kano State, the rate is 3, 849 tonnes/day (Bayero University Kano Consultancy Unit). Generally, the average rate of generation is estimated as 0.5 kg/capital/day.

Biodegradable waste account for over 50% of waste generated with other component estimated at different composition in different States. A recent study carried by the Bayero University Kano Consultancy Unit (March, 2012) estimated the following composition for polythene/cellophane (19%), paper (12.7%), metal (10%), glass (8.7%), plastics (11.3%), fines comprising of ash, dust and sand (12%) miscellaneous (9%) while a study by the Basel Convention Coordinating Centre for Africa in 2009 reveals that 70% of all imports were used electronic electrical equipment of which about 30% could be described as E-Waste.

Until recently, the concept of land filling was used to dump waste material for disposal. Therefore, not much care was taken about their construction. Placing the waste in the Earth's upper crust was considered as the safest practice of waste disposal. But with rapid industrialization and urbanization, land filling has metamorphosed. As uncontrolled landfills have shown potential of polluting various parts of the environment and many accidents have also happened, regulations have been imposed on landfill location, site design and their preparation and maintenance. A certain degree of engineering was made mandatory for landfills.

2.3 Landfill Site Selection

According to ISWA 2013, In order to select an appropriate site for a landfill, several issues are to be considered;

i. neighborhood (distances from residential area, from waterways and water bodies, and from airports)
ii. geological and hydrogeological conditions in the area
iii. seismic conditions in the area
iv. existence of groundwater and its current (and future) utilization
v. risk of flooding, subsidence and landslides
vi. transport distances and existing infrastructure (e.g., access roads)
vii. access to intermediate and final cover material
viii. topography of site

2.3.1 Neighborhood and other sites

Landfill sites should not be located in the immediate proximity of occupied dwellings, waterways and water bodies. A minimum distance of at least 500 m should be provided. As urban settlements tend to expand very fast in many tropical countries, city developments and future land use should be anticipated when selecting a landfill site.

In case of an airport in the neighborhood larger distances to the landfill site are recommended (potential hazard to aircrafts due to bird strike). Depending on the airport flight paths distances of more than a few kilometers may be recommended. Besides the requirement of a minimum buffer zone between residential areas and the landfill site, distances should not be too large, as transport costs for waste increase almost linear with the distance. So sites should be located outside present and future residential areas, but close enough in order to keep transportation costs as small as possible. Around the landfill a so called buffer zone (cultivated area – bush vegetation) for segregating the landfill from residential area should be installed. This buffer zone should prevent vector migration to residential area, absorb scattered dust driven by landfill equipment and waste collection vehicles, and reduce noise and odour nuisances of the landfill operation.

2.3.2 Geological and hydrogeological conditions

Information about the geological and hydrogeological conditions at the site is crucial for determining the potential risk of emissions from the landfill for the underlying soil and groundwater. In order to reduce construction costs for expensive base liner systems, landfills should be sited at locations where the subsurface layers are characterized by low hydraulic conductivity (hydraulic conductivity of less than 1 x 10-8 m/s). In the best case a subsurface layer of very low hydraulic conductivity could substitute a man-made base liner, and thereby significantly reduce landfill construction costs. Knowledge about the groundwater flow direction is necessary in order to develop a monitoring system for the groundwater (groundwater monitoring wells up- and down gradient of the landfill).

Information about the geological and hydrogeological conditions at the site could be obtained

by geological maps (on the superficial level), or are to be investigated during the site selection process (e.g. soil borings, in situ cone penetration test).

2.4 Landfill Design

Leachate emissions from landfilled waste are a crucial problem due to the high organic content of waste on the one hand, and due to the high precipitation rates on the other. Hence adequate landfill design is urgently required. One of the principles for landfill design is isolating the waste from the surrounding environment at low costs, which should consider construction as well as operation costs. The isolation from the environment (at the base of the landfill) can be accomplished by a base lining system.

2.4.1 Base lining system

In affluent countries landfill regulations often require a composite liner at the landfill base. This composite liner (Figure 2.2 b) usually consists of a clay layer (of 40 to 80 cm thickness) and a high density polyethylene (HDPE) sheet. The later in particular is expensive and hence often not affordable for landfill operations in developing countries. Hence, it is recommended to use a “single” baseliner system consisting of compacted clay layers (see Figure 2.2 a). The clay material should preferably be accessible in the vicinity of the landfill site, in order to minimize transportation costs and traffic. Thus, site selection is crucial for the overall costs of landfilling. Requirements for the compaction of the clay and the required hydraulic conductivity can be derived from international regulations on landfill construction Sometimes it might be sufficient to slightly reduce the low permeability of the existing soils, simply by loosening the upper 20 to 30 cm of the soil and subsequently compaction of this layer with heavy equipment. Specific costs for the construction of base lining systems can thereby be reduce to less than 1 US-$ per m². In comparison construction costs for base lining systems in the US are reported to 20 to 30 US-$/m², whereas in the European Union costs could even be much higher, up to 70 US-$/m². The surface of the liner should be sloped with at least 2 %.

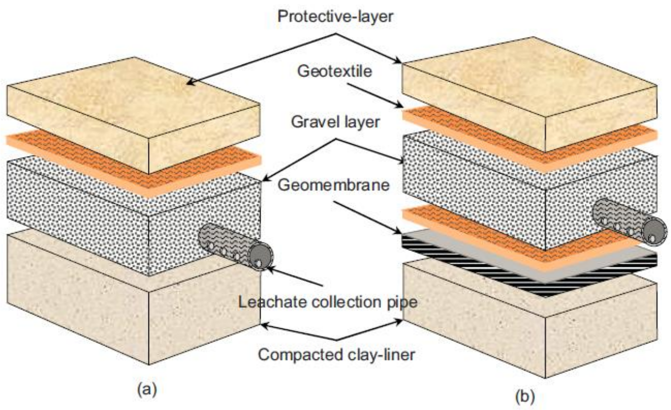

Figure 3: Schematic of Base Single-line System. Figure 4 Compost Lining System. Source (ISWA, 2013).

2.5. Designed landfill capacity (DLC)

The DLC is the ultimate designed volume of the landfill for the target lifespan, including the volume of waste and covering material that is landfilled and compacted. The DLC is used to determine the physical size of the landfill and the total area required (Revised Draft, 2004).

The ADLV is the most important parameter in the equation necessary to determine the size of the landfill site for the proposed target lifespan. It is generally determined by calculating the correlation factor between the estimated average annual volume or amount of the waste brought into landfill, by the reduced volume after compaction in the landfill. The average annual volume of waste has to be estimated based on the historical records of the actual volume of waste landfilled, at least, for the past five years.

Alternatively, the ADLV can also be estimated by comparing the past records of the vehicle haulage volume (ton) and the landfill volume (m3) of the other LAs with similar urban populations and employing similar wastes treatment methods. If only the data on the carrying capacity of vehicles is available, then the vehicle haulage volume (VHV) may be calculated using the following equation:

VHV [ton] = [Carrying Capacity (m^3)] x [Typical Specific Gravity of Waste (ton/m^3)] (2.1)

The ADLW is the estimated weight of solid wastes to be landfilled during a particular year. It is estimated by taking into account of the types of waste, the average weight of the waste, the generation rate per capita and the population concerned. The average weight of the waste and the generation rate can be determined based on the historical records and past trends of the actual weight of waste collected from the households. The projected solid waste amount should be estimated, up to the target lifespan, with increments of 5-year intervals. The solid waste amount will steadily increase year by year due to the following factors:

i. Increase in the population
ii. Expansion of service area coverage
iii. Increase in per capita generation rate with the rise in living standards
iv. Increase in commercial activities

2.6 Function of the sanitary land fill system

The main functions of a sanitary landfill system are as follows:

i. Storage and Treatment
ii. Environmental Protection
iii. Land Development

The Sanitary landfill system must be designed with consideration towards preserving the living environment by preventing undue incidents such as overflowing of the waste and leachate seepage; propagation of vectors and attracting wild animals; scattering of wastes; and emission of unpleasant odour. As a waste disposal facility, the main function is in the storage and treatment so that the waste may be stabilised and the volume reduced. However, landfills are treated as dirty and undesirable by the neighbouring residents who tend to be more concerned about the environmental aspects and on land development aspects. Thus, it is necessary to plan and design the landfill system which can maintain a balance of the three functions (Revised Draft, 2004).

2.6.1 Storage and treatment

An effective sanitary landfill must be designed to have the capability of storing and safely containing the waste with in its boundary and retaining the leachate from seeping out and polluting the surrounding environment. It is also necessary to prevent the waste from scattering and emitting unpleasant odour. It is essential that leachate quantity be reduced and treated. The amount of emitted gasses such as methane should also be minimized. The storage and treatment function can be further divided into three standard sub functions; these are the retaining function, seepage control function and treatment function.

2.7.1.1 Retaining function

Each of the designated cells must be filled in an orderly manner and the landfill site must be kept in a workable condition throughout target lifespan of the site. The stability of the closed landfill must also be maintained over a predetermined period. Suitable retaining bunds, embankments, walls and dykes must be provided to retain the waste. Such waste retaining facilities must be maintained throughout the operational period, closure and also during the post-closure ultimate use period. The retaining structures must be robust and constructed to prevent against erosion and weathering.

2.7.1.2 Seepage control function

Leachate from the landfills must not be allowed to seep into the waterways, rivers, ground water sources, aquifers etc. Pollutants from the waste can be transported by contaminated water inherent in the waste layers and by rainwater or ground water percolating through the waste. As precautionary measures, it is essential that any excess water seeping in from the surrounding to the landfilled waste be minimized and diverted by the construction of surface drains for the storm water run-off and drainage. Liner may also be installed at the bottom and sides of the landfill area as to prevent the leachate from seeping through and also to divert and channel the leachate to the leachate collection pipes and to the treatment facilities. The selection of the liner material must take into account of the stabilization period and should last throughout this period. Alternatively, selecting sites with non-permeable ground layer such as clay may be advantages as these layers will acts as natural barriers. Once the landfilled waste has stabilized over a period of time, the effects on the surrounding environment due to leachate and gases will be lesser.

2.7.1.3 Treatment function

The landfill can also be considered as a treatment facility whereby the solid waste undergoes a process of decomposition and stabilization. The biological, physical and chemical changes occurring in the waste layers play an important role in the treatment process. Municipal solid wastes contain a large amount of organic putrescible matter and depend entirely on bacterial decomposition in the stabilization process. As for the by-product of the decomposition process, such as leachate and gases, suitable treatment facilities should be provided in order to prevent and minimize further contamination and pollution to surrounding environment.

2.7.2 Environmental protection function

The environmental protection function is essential to minimise and prevent harmful effects to human health and to protect the surrounding natural environment. Such harmful effects are caused by problems associated with the discharge of leachate for the landfill, emission of volatile greenhouse gases, foul odour, vectors and other forms of pollutants such as noise and disturbances.

2.7.2.1 Leachate (prevention of ground and surface water pollution)

The quality of the leachate discharged from sanitary landfill system are bound by a series of environmental regulations and laws such as "Environmental Quality Act 1974", "Environmental Quality (Sewage and Industrial Effluents)", and other standards and by-laws adopted by the Local Authorities. Therefore the leachate discharge from sanitary landfill system must be treated to comply with the requirements as stipulated in the relevant laws. Leachate from the sanitary landfill site may be harmful and contaminate the water sources if it was discharged without treatment. Adequate and effective leachate treatment system must be provided with sufficient treatment and retention capacity to handle the leachate quantity, and provided with enough buffer to treat any temporary increases in the quantity that may be caused by excessive rainfall.

2.7.2.2 Vectors

Landfill areas tend to become breeding and feeding for vectors and animals such as flies, rodents, birds and stray dogs. In order to minimise and prevent such occurrences, daily cover soil should be laid to cover up the landfilled wastes. Insecticides may be sprayed over the area to prevent the breeding of flies and insects. Perimeter fence should be installed to prevent wild and gracing animals from entering the site. This will also prevent human scavengers from getting to the waste.

2.7.2.3 Gaseous products

The main gaseous products emitted from the sanitary landfill site are methane, ammonia and hydrogen sulphide. The composition of the gases depends on the decomposition conditions of the waste layer, i.e. either aerobic or anaerobic. Attention must be paid to the anaerobic landfill that contains mostly organic waste which can produce significantly high concentration of methane. Excessive build-up of such volatile gasses may ignite and cause explosions. Such hazardous conditions may persist long after the landfill has been closed. Most of these gasses are harmful to human and the surrounding but the amount produced at the landfill are generally low and not concentrated enough to have any immediate effect. It may be necessary to install gas-venting system to facilitate the dispersion of the gasses to the atmosphere.

2.7.2.4 Unpleasant odours

There are generally two kinds of unpleasant odour that are emitted from the landfill site, i.e. the odour from the fresh putrid waste matter and the odour produced as theresult of the decomposition process. It may be necessary to control the dispersion of such odour to the surrounding environment especially when the landfill site is located near populated areas. The recommended measure is to provide suitable cover material on the waste layer at the end of the day's activities. Another more enhanced method is to provide gas collection and treatment facilities.

2.7.2.5 Noise pollution and disturbances

Excessive noise and disturbances that may be cause by dusts or vibrations emitting from the landfill are a nuisance and causes discomfort to the neighbouring population. These are usually caused by activities associated with the waste transport vehicles, machinery used at the site or from the leachate treatment facilities. For the landfill located near populated areas, it may be necessary to improve on the way the site is operated by reviewing the waste transportation system, and the selection and use of machinery and equipment so as to limit the effects of noise pollution and nuisance.

METHODOLOGY

3.1 Design of Sanitary Landfill

The design of sanitary land fill entails the followings:

1. Determination of the lifespan/target year
2. Location of a suitable site
3. Carrying out financial analysis and determining the construction schedule of the landfill.

Other considerations must also be taken into account, such as

4. The projected quantity and analysis of wastes haulage as well as consideration of the actual conditions on the designated service area. Such process of planning, surveys and preparation of the detailed design may take several years. Hence, in order to prevent excessive buildup of waste, it is recommended to provide some reserve margin or buffer in the plan so that the life span of landfill may be increased by a further 10-year period, if necessary, to allow for the transition period.

Given the poor situation of waste management and landfills has also been the failure of existing landfills to attract private participation, the following new methodology of landfill design is proposed for development to attract private participation in waste management by providing economic gains. The proposed design is based on an integrated approach to waste disposal and energy generation. This approach can be applied only to the proposed new landfills. It may not be applied to the existing landfills.

The following assumptions will be made:

1. Waste is segregated at source and should contain very little fraction of recyclable material when it reaches the landfill site.

Direct shipment of waste is considered in most of the cases as the proposed landfills

with modified designs could be located in different parts of the mainland leaving a wider scope for minimization of transportation cost and efficient waste collection.

In this design approach, in contrast to the conventional approach, land requirement will be determined for the waste generation level and for a given life of landfill, the required number of cells is decided upon.

The following parameters will be considered

i. Density of waste in landfill ρ, kg/m^3
ii. Total waste generated per day (tons)
iii. Annual waste generation (tons)
iv. Compostable fraction of solid waste
v. Non-organic/reuseable fraction of solid waste
vi. Collection efficiency
vii. Fraction to be landfilled
viii. Landfilling efficiency
ix. Depth of fill (m)
x. Ratio of volume of cover soil to the volume of waste
xi. Volume of waste after landfilling including daily cover (daily), m^3
xii. Base length of land fill
xiii. Breadth of base

With 1:1 slope, the dimensions of each cell can be calculated by trial and error for any given set of waste generation data (Yedla, 2005). Maturation period of three years is considered for this modified design of landfill. This has been assumed based on the anaerobic digester demonstrated for the digestion of market waste (IIT, 1997). Thus, the entire waste can be managed by adopting the rotation process. This could be fixed for any city depending on waste generation rates and the conditions for the waste maturation. The layout can be designed based on population distribution of the city under consideration. It could even be distributed at different places based on the geographical conditions of the city under consideration.

For faster gas generation, depth of the landfill should be in the range of 3.5 m (Bhide, 1994; Mosher *et al.*, 1999). Compaction efficiency is the driving parameter for both area requirement and gas generation.

3.2 Basic Design Parameters

The followings are the basic design parameters

3.2.1 Target lifespan / target year

The target lifespan shall be the designed operational duration of the landfill site and should be set at approximately 10 years of operations. This corresponds to the policy of implementing adequate solid wastes treatment projects from the long-term plan.

3.2.2 Designed landfill capacity

The Designed landfill capacity (DLC) is determined by calculating the product of the sum of planned waste to be landfilled (ADLV) and soil covered (CMV) per year, by the number of years that the landfill is to be operated.

DLC [m^3] = (ADLV [m^3/year] + CMV [m^3/year]) x target lifespan [year] *(3.1)*

The Annual Designed Landfill Volume (ADLV) is determined by dividing the Annual Designed Landfill Weight (ADLW) by the specific weight (SWW) (or weight per unit volume) of the solid waste that is landfilled and compacted.

ADLV [m^3/year] = ADLW [ton/year] / SWW [ton/m^3] *(3.2)*

The Cover Material Volume (CMV) is determined by dividing the Annual Designed Cover Material Weight (ADCMW) by the specific weight (SWCM) (or weight per unit volume) of Cover Material which is landfilled and compacted.

CMV [m^3/year] = ADCMW [ton/year] / SWCM [ton/m^3] *(3.3)*

Usually, after determining DLC, the site which can secure the capacity which fills DLC is selected. The required area for landfill site depends on the situation of a securable site.

However, when DLC is first determined by the reason the site was already decided etc., target lifespan will change according to DLC.

Assumptions

Increase in the generation rate per capital = 2% per year

Increase in population = 4% per year

Table 3.1 Densities of Types of Waste

Type of waste	Range (kg/m^3)	Typical (kg/m^3)
Normally compacted	362 – 498	450
Well compacted	590 – 742	600

2006 – Sample population = 200,000

Service coverage = 20%

Generation of domestic waste = 0.80kg/capital/day

Commercial and institutional waste = 30 tons/day

The total amount: $200{,}000 \times 0.20 \times (0.80 \times 10^{-3}) + 50 = 85 tons/day$

$200{,}000 \times 1.04^5 = 243330.6 \cong 234{,}331$

Service coverage increase by 10% = 30%

Generation rate of domestic waste: $0.30 \times 1.02^5 = 0.3312$

Commercial and institutional waste (80% per year increase): $30 \times 1.08^5 = 44.08$

The projected total amount: $243{,}331 \times 0.30 \times (1.0 \times 10^{-3}) + 44.08 = 117.0793 tons/day$

Thus the projected solid waste for the first 5 years will increase from 85 tons/day to 226.4 tons/day.

The specific weight of solid waste (SWW) (weight per unit volume) of solid waste that is landfilled and compacted. Since solid waste is not homogeneous and also subjected to the variation in the compaction, the specific weight is usually expressed in the raise of values. Typical values are assumed.

Source ("integrated solid waste management engineering principles and management issues")

4.0 Calculation of Design Flow

The stormwater volume depends on rainfall intensity, catchments area, topography and land-use. It can be generally estimated from the following rational equation:

$$Q = \frac{1}{360\,CIA} \quad (3.4)$$

where;

3.2.4 Determination of Cross Sectional Area

Generally, the cross section for open drain is either rectangular or elliptical. It is necessary to design for a slightly bigger cross sectional area to compensate the accumulation of sands, sediments and gravels by using the following equation:

$$S = \frac{Q}{V} \quad (3.5)$$

where

S is the cross-sectional area of flow (m^2)

Q is the discharge volume (m^3/sec)

V is the average flow velocity (m/sec)

The average flow velocity can be calculated by Manning's equation as

$$V = \frac{1}{nR^{\frac{2}{3}}T^{\frac{1}{2}}} \quad (3.6)$$

where,

V is the average flow velocity (m/sec)

N is the Manning's coefficient of roughness

T I the gradient of channel

R is the hydraulic Radius (m) = S/P

where,

S is the cross-sectional area of flow (m^2)

P is wetted perimeter (m)

Q is the stormwater volume (m3/sec)

C is the coefficient of flow (select appropriate volume in accordance with topography of landfill catchments area or vegetation, etc.)

I is the rainfall intensity (storm recurrence interval of 10 to 15 years (mm/hr)

A is the catchments area (ha)

Coefficient of flow (0.6)

Rainfall intensity (100 mm/hr)

Catchments area (5ha)

$$Storm\ water\ volume = \frac{1}{360 \times 0.6 \times 100 \times 0.5} = 0.833 m^3/sec$$

In case the cast-in place concrete drainage (width of 0.8m, a depth of 0.5m, Manning's coefficient of roughness of 0.017, slopes of 1/100) is considered, the cross-sectional area of flow will be calculated as follows.

$$Hydraulic\ radius = \frac{0.4}{1.8} = 0.222m$$

$$Average\ flow\ velocity = \frac{1}{0.017} \times \frac{0.2222}{3} \times \frac{0.011}{2} = 2.16$$

$$Cross-sectional\ area\ of\ flow = \frac{0.833}{2.16} = 0.39m^2$$

Thus, the calculation result of the cross-sectional area of flow is just the same size with the considered drainage, the drainage can be adopted. If the calculation result of the cross sectional area of flow is widely different with the primary considered drainage, drainage size should be re-considered (Revised Draft, 2004

5.0 Conclusion

Based on the field study, analysis of the results and physical assessment conducted during the research, the following conclusions have been drawn.

i. The practise of open landfilling is not fully incorporated due to the fact that it is practised on a level surface and wastes are burnt so as to reduce the size of the waste rather than daily covering using laterite or clay.

ii. Combustible wastes are more generated than non-combustible waste especially in Ado Ekiti due to the commercial activities being carried out.

iii. Wastes generated in residential and commercial areas based onclass of waste, food material class has higher percentage than any other type of waste.

iv. More research needs to be done on the design, construction and utilization of sanitary landfill

5.1 Recommendations

From my research being carried out and visitation to different existing landfills both in Ado Ekiti and Lagos and contribution to the work, the following recommendation has been made:

i. The government should take the management of waste serious because it can serve as a source of wealth, and help to keep a sustainable environment.

ii. A sanitary landfill should be built in strategic places in Nigeria so that recycling, reuse and recovering of materials will be encouraged.

iii. Geotechnical investigations should be incorporated when Designing for a landfill

iv. Frequent visit should be made to an existing and proposed landfill by professionals and researcher in environmental engineering related projects.

v. Landfill should be designed based on all types of decomposable waste since they are highly generated and decomposes easily.

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