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A PRELIMINARY INVESTIGATION INTO THE OPERATIONAL REQUIREMENTS OF A SANITARY LANDFILL FOR CRUTECH COMMUNITY, SOUTHERN, NIGERIA: A REVIEW

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Abstract
The Cross River University of Technology (CRUTECH), located at540252, is one of the Universities in the south-south region of Nigeria. It was established in 2002 by the defunct Polytechnic, Calabar. It has a current population of over 18,000 students, 2,000 staff, supporting staff, and staff's relatives residing in a land area of less than 500ha, but with no feasible municipal waste management/recycling facility clearly in place. The University's municipal waste generation per capita per day is roughly 2.67kg, implying that not less than 19,491,000kg of waste is generated annually. This makes practicable and satisfactory waste disposal, oftentimes, a problem. This study was aimed at evaluating the preliminary requirements for the possible design, construction, and management of a workable sanitary landfill in the University community, as well as the contiguous land areas based on existing literature and operational guidelines for littoral regions like Calabar where the University is domiciled. Based on the review study, a 5m x 5m x 3m sanitary landfill has been proposed for design, construction, and management as a pilot project/model for a start for the community.

Keywords: Design, construction, management, sanitary landfill, University community, contiguous land

1. Introduction

Municipal solid waste (MSW) production in India and other developing economies like Nigeria, has increased significantly as a result of profligate population growth and economic advancement. Solid waste creation in India is projected to be 100g per capita per day in small towns, 300-400g per capita per day in medium cities, and 500g per capita per day in large cities (FEPA, 2014). Studies show that Nigeria generates 42 million tons of waste annually, which makes it more than half the volume generated by the entire sub-Saharan (62 million tons). Lagos State alone spends billions on waste disposal (Antigha, 2022). According to current trends, the quantity of garbage generated per capita is expected to rise at a rate of 1% to 1.3% every year. In 1987, the World Commission on Environment and Development defined sustainable development as development that meets the demands of the present without jeopardizing future generations' ability to satisfy their own needs. Landfill has been defined as the engineered disposal of trash onto and into land in such a way that contamination or harm to the environment is avoided and land that can be used for other purposes is provided through restoration. In general, a sustainable landfill is constructed and operated in such a way that both short-term and long-term ecological apprehensions are tolerable (FEPA, 2014). Over the last few years, experimental testing and field preliminary studies have been done to create and expand landfill processes and designs to encourage solid waste degradation, such as reducing leachate treatment time, enhancing methane production, and hastening waste plummeting. As a result, air space regaining and reduction in the life span of pollution have been made possible. Leachate recirculation and the addition of nutrients and sludge are two techniques used to improve the degradation process (FEPA, 2014). Leachate recirculation in landfill bioreactors is advancing in acceptance as a competent method to the enhancement of the microbial breakdown of municipal solid wastes.

Sanitary landfill remains the most cost-effective solid waste disposal technique for most developing-country and cities. This is because solid waste composting alone costs 2 to 3 times more than sanitary landfilling, while incineration, at its best, costs 5 to 10 times over. A sanitary landfill is basically a self-contained and engineered bioreactor structure that encourages anaerobic biodegradation and consolidation of compacted trash materials within confining layers of compacted soils. In a properly designed, constructed and managed sanitary landfill, there is no annoying effects of frequent burning, smoke, flies, windblown litter, or unattractive rubbish mounds (Acosta et al, 2012).

In a proper sanitary landfill, refuse is not exposed to rainfall, surface runoff, or groundwater. Leachate is produced simply by a small amount of infiltration that reaches the waste deposit and absorbs waste biodegradation by-products. While sanitary landfills generate less leachate than open dumps, leachate concentrations are substantially greater – organics by a factor of more than ten – and hence, leachate must be satisfactorily managed. Sanitary landfills in arid areas, where leachate generation is negligible, may have less rigorous construction standards than those in wet zones. Equally, sanitary landfills on coastal lands underlain by naturally saline and non-potable groundwater may have less stringent construction standards than those in inland areas overlain by possibly useable groundwater regimes. In these places with low effect potential, impermeable landfill lining may be superfluous during design. As an alternative, steps to improve natural attenuation through the soil's adsorption, precipitation, filtration, and ion exchange capabilities should be addressed. All home garbage can be reused or recycled into value-added products such as vermi compost, biogas, and bio char, but only with efficient waste separation processes (Acosta et al., 2012). In Europe, America, and other industrialized countries, the notion of waste separation at source is commonly used to ensure that valuables and useful garbage are separated before being mixed with useless rubbish. This method lowers the possibility of valuable waste stream contamination while also increasing the capacity for proper waste management.

In practice, waste separation is the categorizing of garbage to ensure that each waste generated is categorized, oftentimes, based on sorting codes. This includes sorting through waste to determine what may be recycled, what should be disposed of in a landfill, and what requires special handling, such as hazardous waste.

The aim of this study is to examine the preliminary requirements for a sanitary landfill design and its operation in a typical littoral environment. The objectives of the study include:

i. To examine the operational needs of a typical sanitary landfill;
ii. To determine the requirements in siting and management of a typical sanitary landfill in the University Community of a littoral region
iii. As a further study, to investigate the environmental impact(s) of sanitary landfill (if any), arising from its operation.

2.0 Conceptual framework

2.1: Waste Management and Sanitary Landfilling

Landfilling is a significant but not the only chore in the scope of actions of waste management. Municipal waste management includes the tasks:

- waste gathering and conveyance
- recycling of organic waste and other recyclable constituents
- pre-treatment of waste
- dumping (landfilling)

Table 1 shows an example of a fully integrated waste management concept, typical for many medium-sized towns in Western Europe. This scheme follows the line

- to avoid waste wherever it is possible
- to establish effective recycling systems
- to treat wastes before disposal
- to ensure a long-term non-environmental polluting waste disposal

Table 1: Scheme of Municipal Waste Management

Origin of Waste	Household Waste			Non-Household Waste		
Type of Waste	Residual Waste	Biowaste	Recyclables	Commercial Waste	Construction Waste	Sewage Sludge
Avoidance of Waste	Advisory Service for Households			Advisory Service for Companies		
Storage for Separate Collection	Black Bins	Green Bins	Public Containers	Bins/ Containers	Containers	Storage Basins
Waste Collecting Institution	Municipality			Municipality or Private Companies	Construction Company	Operator of Sewage Plant
Treatment before Recycling	-	Composting	Sorting	Sorting	Sorting/ Crushing	Dewatering
Recycling Products	-	Compost	Paper/Glass	Paper/ Cardboard	Split/Gravel	Agricultural Fertilizer
Treatment before Disposal	Biological or Thermal Treatment	-	-	Thermal Treatment	-	(Thermal Treatment)
Disposal	Landfilling	Landfilling of Residuals	Landfilling of Residuals	Landfilling	Landfilling of Residuals	-

Table 1 furthermore shows that effective waste management has to take into consideration the various types of waste. Each "waste stream" needs special collection, treatment, and marketing or disposal systems.

Apart from such an advanced system, waste management has to cover two main tasks in each municipality all over the world which is a waste collection (to keep the streets tidy), as well as waste disposal.

In countries with limited monetary and scientific resources, landfilling is the fitting method of waste disposal. Countries with low population density and amply available lands can use landfill technology for many years as the bedrock of their management tactic. Building on this base, a comprehensive waste management concept, adapted to the regional conditions, can be put in place.

Considering this important role of landfilling in the field of urban development, the requirements on landfill technology shall now be discussed

2.2: Landfills Concept

Packing any waste material in a landfill presents numerous potential problems. One such problem is the conceivable contamination of soil, groundwater, and surface water that may occur as leachates generated by water or liquid wastes moving into, though, and out of the landfill drifts into contiguous areas. With the possibility of hazardous wastes, landfills should be designed to prevent any waste or leachate from ever moving into adjoining areas. Leachate is described as a liquid that has permeated through the layers of waste material. Thus, leachate may be composed of liquids that are initiated from a number of sources, including precipitation, groundwater, consolidation, initial moisture storage, and reactions associated with the decomposition of waste materials.

The chemical quality of leachate varies as a function of a number of factors, including the quantity produced, the original nature of the buried wastes materials and the various chemical and biochemical reactions that may occur as the waste materials decompose. In absence of evidence to the contrary, most regulatory agencies prefer to assume that any leachate produced will contaminate either ground or surface waters; in the light of the potential water quality impact of leachate contamination, this supposition appears rational.

2.3: Leachate Control

The amount of leachate formed is affected to some extent by decomposition reactions and preliminary moisture content. It is largely governed by the amount of external and initial moisture content which in itself is principally influenced by the amount of external water entering the landfill. Thus, a key first step in controlling leachate migration is to limit production by averting, to the level practicable, the entry of external water into the waste layers. A second step is to collect any leachate that is produced for subsequent treatment and disposal. Techniques are currently available to limit the amount of leachate that migrates into adjoining areas to a virtually negligible volume, as long as the integrity of the landfill structure and leachate control system is maintained. The bottom layer of soil may be naturally existing material or it may be hauled in place, and compacted to specifications following excavation to a suitable subgrade. In either case, the base of the landfill should act as a liner with some minimum thickness and very low hydraulic conductivity (or permeability). The barrier soil may be treated to reduce its permeability to an acceptable level. As an added factor of safety, an impermeable synthetic membrane is shown placed on the top of the barrier soil layer to form a composite liner.

Immediately above the bottom composite liner is a leakage detection drainage layer to collect leakage from the primary liner, in this case, a geo-membrane. Above the primary liner are a geo-synthetic drainage net and a sand layer that serve as drainage layers for leachate collection. The drain layers are composed of the sand layer that serves as drainage layers for leachate collection. The drain layers composed of sand are typically at least 1 ft thick and have suitably spaced collection pipes, avoiding a significant build-up of head and limiting leakage. The liners are sloped to prevent ponding by encouraging leachate to flow toward the drains. The net effect is that very little leachate should percolate through the primary liner and virtually no migration of leachate through the bottom composite liner to the natural formations below should occur.

Drainage layers, geo-membrane liners, and barrier soil liners may be referred to as the leachate collection and removal system or a double liner system. After the landfill is closed, the leachate collection and removal system serves basically in a backup capacity. However, while the landfill is open and waste is being added, these components constitute the principal defense against contamination of adjacent areas. When the capacity of the landfill is reached, the waste cells may be covered with a cap or final cover, typically composed of four distinct layers.

At the base of the cap, there is a drainage layer and a liner system similar to that used at the base of the landfill. The top of the barrier soil layer is graded so that water percolating into the drainage layer will tend to move horizontally towards some removal system located at the edge of the landfill. A layer of soil suitable for vegetative growth is placed at the top of the final cover system to complete the landfill. This upper layer is about 2 feet thick having loamy and silty soil, graded so that runoff is restricted and infiltration is controlled to provide moisture for vegetation while limiting percolation through the topsoil. Runoff is promoted but is controlled to prevent excessive erosion of the cap. Vegetation such as grasses best serves this purpose.

The combination of site selection, surface grading, transpiration from vegetation, soil evaporation, the drainage through the sand, and the low hydraulic conductivity of the barrier soil and geo-membrane liners serves effectively to minimize leachate production from external water. The cap should be no more permeable than the leachate collection and removal system so that the landfill will not gradually fill and overflow into adjacent areas following the abandonment of the landfill.

2.4: Types of-Sanitary Landfill

According to Jorge Jaramillo (2003), three types of sanitary landfills could be offered for the final disposal of municipal solid waste.

2.4.1: Mechanized Sanitary Landfill

Large cities and populations that generate more than 40 tons of waste per day are the target market for the mechanized sanitary landfill. Researching the amount and type of waste, planning, site selection, the amount of land, the design and execution of the landfill, the infrastructure needed to receive the waste and control operations, the amount and management of investments, and the operating and maintenance costs are all part of the process of the mechanized sanitary landfill.

A solid waste compactor and specialized earth-moving machinery, such as a track-type tractor, backhoe, loader, dump truck, etc., are needed to run this kind of sanitary landfill.

2.4.2: Semi-Mechanized Sanitary Landfill

When a certain municipality wants to dispose of 16 to 42 tons of MSW per day in a sanitary landfill, it is best to utilize heavy machinery to supplement manual labor, ensuring that the waste undergoes adequate compaction and the fill banks are properly stabilized, hence extending the landfill's usable life. This "semi-mechanized" landfill might be operated by a farm tractor outfitted with a bulldozer or blade, as well as a scraper or roller for compaction

2.4.3: Manual Sanitary Landfill

This is a customized adaption of the sanitary landfill project for small settlements with garbage production rates of less than 15 t/d.

The name "manual" implies that the process of compacting and restricting garbage can be accomplished by a group of laborers using hand tools (labor-Intensive technology).

In this case, the selection of a sanitary landfill is mostly determined by the amount of solid waste generated.

2.5: Construction Methods for a Sanitary Landfill

A sanitary landfill's construction process and ongoing functioning are largely influenced by the terrain of the surrounding area, though they also depend on the kind of soil and depth of the water table. Jorge Jaramillo, 2003, states that there are two main methods for building sanitary landfills according to the Guidelines for the design, construction, and operation of manual sanitary landfills.

2.5.1: Trench Method

This method is used in flat regions and consists of periodically digging trenches two or three meters deep with a backhoe or a track-type tractor. Some trenches have been dug as deep as 7m. The solid waste is placed and spread in the trench, later to be compacted and covered with the excavated soil.

Special care should be taken during rainy periods since water can flood the trenches. To prevent this, drainage ditches should be dug around the perimeter to divert the waters, and internal drainage can also be provided for the trenches. In extreme cases, a roof can be erected over them, or the accumulated water can be pumped out. The slopes or walls should be cut as shown in figure 1.

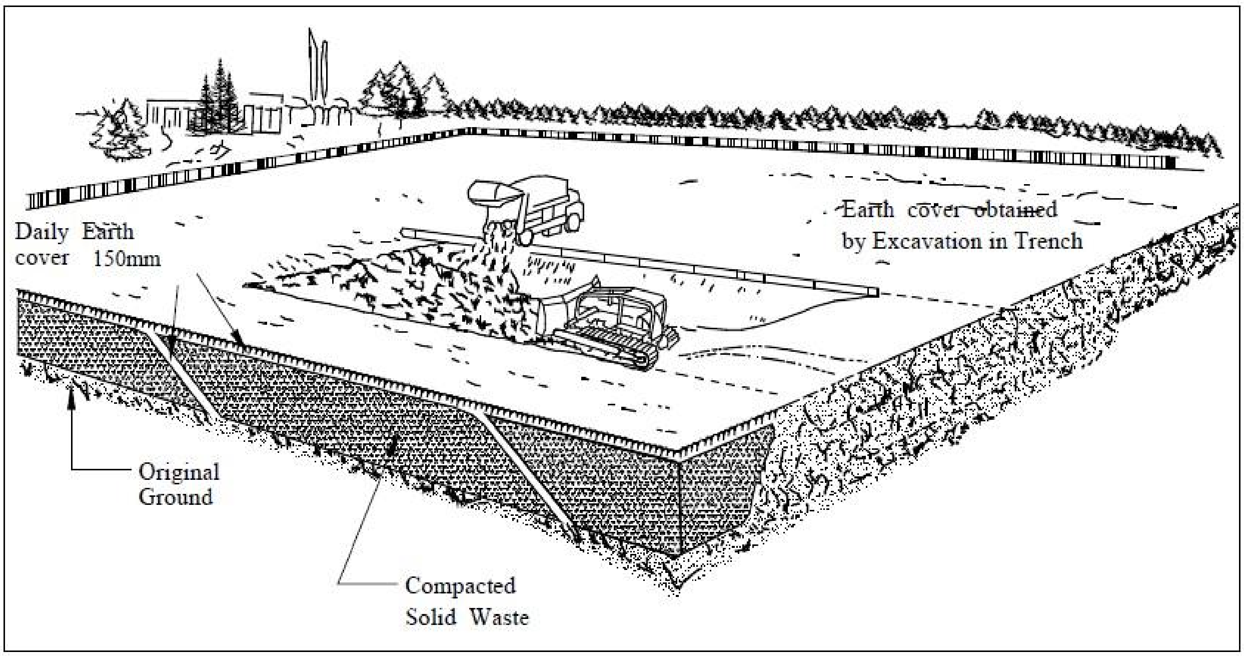

Figure 1. showing the trench method of landfilling solid waste

2.5.2: Area Method

In relatively flat areas where it may not be feasible to dig pits or trenches to bury the waste, like in Kapchorwa district, it can be deposited directly on the original ground, or partial clearance is done, and the terrain made waterproof. In these cases, the cover material will have to be brought from other places or, if possible, extracted from the surface layer. The pits are made with a gentle slope to prevent landslides and ensure greater stability as the landfill rises. The area method can also be used to fill natural depressions or abandoned quarries that are several meters deep. The operation of unloading and construction of the cells should begin from the bottom up.

The landfill is made supporting the cells on the natural slope of the terrain, that is, the waste is unloaded at the toe or base of the slope, where it is spread and packed against it and it is covered daily with a layer of soil (see figure 2 below). This activity is repeated as the operation continues, advancing over the site, maintaining a gentle slope of some 18.4 to 26.5 degrees, that is, a vertical/horizontal ratio of 1:3 to 1:2, respectively, and of 1 to 2 degrees on the surface, that is, a 2 to 3.5% grade.

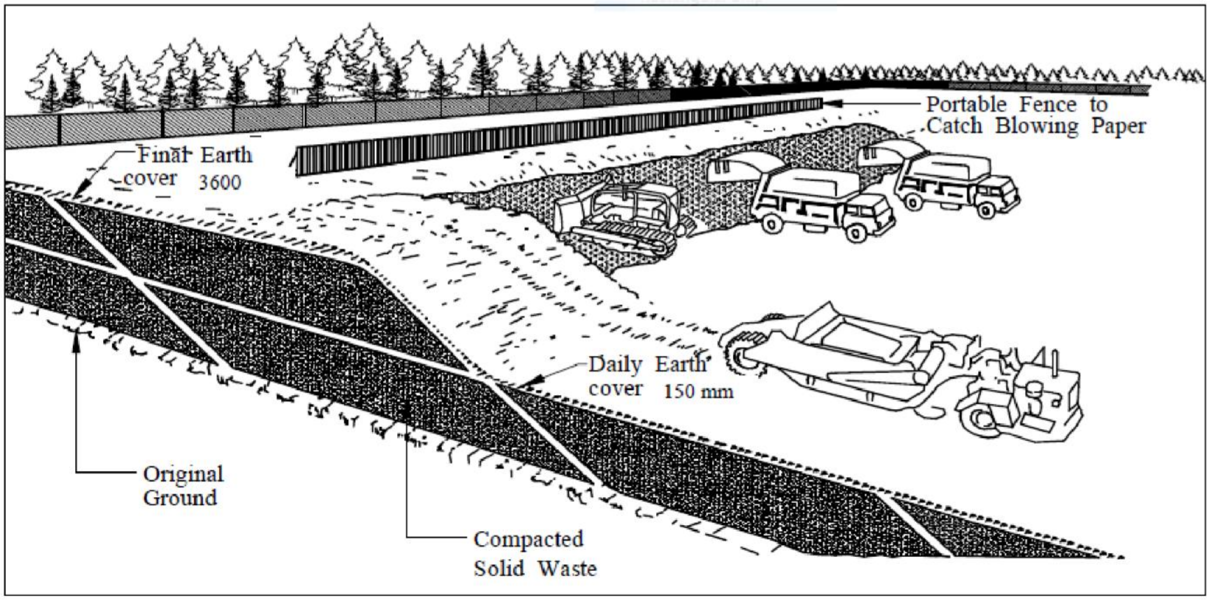

Figure 2: Area type of landfill construction.

2.5.3: Combination of both methods to construct a sanitary landfill

Since these two methods of constructing sanitary landfills use similar operating techniques, it is possible to combine them to make full use of the site and the cover material and to obtain better results.

2.6: Landfill facilities

All the individual functions must be supported and provided with the relevant facilities in order to enhance the functionality and improve the effectiveness of the entire landfill system as an integrated SWM disposal facility. This is according to the technical guideline for sanitary landfill, design, and operation (revised draft, 2004).

The type of facilities to be provided can be divided into 3 groups, namely:

- The Operations Facilities
- The Management Facilities, and
- The Supporting Facilities

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2.6.1: The operations facilities

The operations facilities are the facilities necessary for the actual operations and use of the landfill site, i.e. the retaining structures, bunds, lining system, drainage system, leachate collection and treatment facilities, gas collection system, cover system, etc.

2.6.2: The management facilities

The management facilities are the facilities necessary for the daily management activities of the landfill site. Such include the administration office, weighbridge, weighbridge station, etc.

2.6.3: The supporting facilities

The supporting facilities are the common facilities necessary to support the other management and operations facilities such as access roads, fencing, workshop, vehicle cleansing facility, fire-prevention system, etc.

3.0: Specifications and minimum standards for landfills.

The following minimum standards apply to the design, construction, and operation of landfills according to NSW Environment Protection Authority (EPA), 2000.

These acceptable measures are well-established and reliable techniques for meeting the required outcomes.

3.1.1: Leachate barrier system

The following sections contain acceptable designs, specifications, and operating practices for the leachate barrier system.

The base and walls of all solid waste landfill cells should be lined with a durable material of very low permeability to form a barrier between the waste and the groundwater, soil, and substrata.

This primary barrier system should include the following components, from bottom to top:

A compacted sub-base is 200 millimeters thick to provide a firm, stable, smooth surface of high bearing strength on which to install the liner.

A compacted clay liner at least 1000 millimeters thick, with an in situ hydraulic conductivity of less than 1 x 10^{-9} meters/second; for landfills receiving more than 20,000 tons of waste per year, the liner should include a geo-membrane over the compacted clay liner.

3.1.2: Leachate storage

The design, construction, and operation of the leachate storage dam should meet the following requirements:

The dam must have sufficient leachate storage volume, as determined by using a water balance methodology as explained in the next point.

The dam must have a freeboard that can accept rainfall directly on the dam from a 24-hour rainfall event with a 1-in-25-year average recurrence interval without overflowing. The dam must have a visible marker to indicate the bottom depth of the required freeboard. If the freeboard is exceeded, the occupier must re-establish and maintain the required freeboard. If the dam is in danger of overflowing, an option may be to inject some leachate back into the cells and to stop leachate extraction from the cells.

The dam liner must be designed and constructed to a standard similar to that of the landfill cell liner.

Leachate storage dams should not be constructed over previously landfilled areas, except in exceptional circumstances. Such proposals must clearly demonstrate the long-term geotechnical stability of the proposed dam.

3.1.3: Gravel drainage layers

The gravel drainage material should:

Consist of hard, strong, durable, and clean gravel that will maintain the required performance under the maximum loads likely to be imposed on it in service.

Have a saturated hydraulic conductivity greater than 1 x 10–3 meters/second when tested in accordance with Australian Standard AS 1289.6.7.1 Determination of the Permeability of a Soil (constant head method).

Be relatively uniform in particle size, with a nominal particle size greater than 20 millimeters and a maximum particle size of 40 millimeters, and with not more than 10% of particles smaller than 20 millimeters in diameter and not more than 3% smaller than 0.075 millimeters.

Not have a shape and angularity that will damage the underlying Geo-membrane liner (the best type of gravel is rounded and smooth-surfaced).

Be installed in a continuous layer at least 300 millimeters thick across the entire base of the landfill cell, sloped with at least a 1% longitudinal gradient and 3% transverse gradient.

3.1.4: Landfill gas control

Landfill gas control can be achieved by installing infrastructure to contain, collect and treat landfill gas.

The extent of gas controls will depend on a landfill gas risk assessment for the site. A landfill gas risk assessment should be done initially and should then be updated as gas monitoring data is obtained.

The system of landfill gas controls should address the following requirements. Not all of the following measures will be needed at every site:

Landfill gas should be contained by installing low-permeability engineered barriers on cell floors and walls and in final capping.

Landfill gas should be collected by installing a network of wells, drainage layers, pipework, and an extraction system within the waste. Such a system should be installed in all putrescible waste cells and in other cells producing significant quantities of landfill gas.

Landfill gas controls should be installed progressively during the life of the landfill and post-closure period. Gas collection, extraction, and treatment should start as soon as practicable after the completion of each cell.

The gas management system should be designed and operated to minimize the ingress of atmospheric gases into the landfill.

The leachate management system should be operated in such a way that the leachate does not rise to a level that inhibits gas entry into the gas collection system.

3.1.5: Fire prevention

The following fire-prevention and fire-fighting practices should be followed:

Signs should clearly inform the general public that flammable liquids are not permitted on the site, and there should be an emergency contacts list at the site entrance.

All sealed or contaminated drums should be banned from the landfill unless they are delivered as a specific consignment, the contents of which are clearly identified and suitable.

Flammable solid wastes must not be stockpiled at the premises in excess of the quantity limits imposed on the license.

Fire breaks should be constructed and maintained around all filled areas, stockpiles of combustibles, gas extraction equipment, and site buildings.

Fire-fighting equipment should be installed at the site, including in flammable waste storage areas.

All fire-fighting equipment should be clearly signposted and access to it must be available at all times.

All fire-fighting equipment should be maintained according to a regular schedule (at minimum, weekly visual checks.

Landfill staff should be trained in all of the above fire prevention and fire-fighting techniques.

3.2: Daily covering of waste

Landfilled waste must be covered regularly during operations with a suitable material to minimize odor, dust, litter, the presence of scavengers and vermin, the risk of fire, rainwater infiltration into the waste (and therefore the amount of leachate generated), and the emission of landfill gas.

The daily cover should be applied to the waste each day before the close of business.

The daily cover material should be virgin excavated natural material in the form of soil. A minimum cover depth of 150 millimeters is required.

The main functions of daily cover are to minimize` adverse amenity impacts such as odour, dust, litter, the presence of scavengers and vermin, and the risk of fire.

3.3: Final capping and re-vegetation

All completed landfill cells must be capped and re-vegetated as soon as practicable after the final delivery of waste to the cell. The final capping must:

Reduce rainwater infiltration into the waste and thus minimize the generation of leachate (infiltration from the base of the final cap should be less than 5% of the annual rainfall)

Stabilize the surface of the completed part of the landfill

Reduce suspended sediment and contaminated runoff

Minimize the escape of untreated landfill gas

Minimize odour emissions, dust, litter, the presence of scavengers and vermin, and the risk of fire.

Prepare the site for its future use; this includes protecting people, fauna and flora on or near the site from exposure to pollutants still contained in, or escaping from, the landfill.

During the post-closure period, the occupier must monitor the integrity and performance of the final cap.

4.0: Conclusion and projected future work

With the increase in the admission quota for the University, and the transition of the University from a biased to a conventional University, and with more programs and departments expected, it is likely that more student intake would translate to more wastes generation.

There is therefore an urgent need to put in place a workable, acceptable and conventional approach in waste management and disposal, one of which is the sanitary landfill approach.

It is therefore proposed that a 5m x5m x 3m sanitary landfill be designed, constructed and operated as a pilot project for the university community in order to ascertain in practice, the volume flow rate of wastes of the university community.

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