DESIGN OF A SANITARY LANDFILL FOR KAPCHORWA CENTRAL DIVISION.

FINAL YEAR PROJECT REPORT SUBMITTED TO KAMPALA INTERNATIONAL UNIVERSITY AS A PARTIAL FULFILLMENT FOR THE AWARD OF A BACHELORS DEGREE OF SCEINCE IN CIVIL ENGINEERING

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DECLARATION

We hereby declare that the content in this report is as a result of our collective effort and continuous research and it has never been presented anywhere. This report was done by two members who participated equally to the success of this research.

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APPROVAL

I hereby certify that this final year project report entitled "**Design of a sanitary landfill in Kapchorwa central division**" has been prepared under my supervision. The research was carried out under my supervision and it is ready for presentation to the School of Engineering and Applied Sciences of Kampala International University in partial fulfillment of the requirement for the award of the Bachelor's degree of Science in Civil Engineering for the above students.

MR. NINSIIMA EMANUEL

Signature…………………………………………….. Date……………………………………….

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We also like to acknowledge staff of the department of civil engineering for the continued support through lecturing and laboratory sessions that have led to the success of our project.

To God our provider of wisdom and knowledge, we still say thank you because without him this project accomplishment would have been impossible.

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LIST OF ABBREVIATIONS

NEMA……………………………………………….National Environment management Authority

KCCA…………………………………………………Kampala Capital City Authority

EPA…………………………………………………Environment protection Authority

MSW…………………………………………………Municipal solid waste

EDA…………………………………………………Explanatory Data Analysis

CDA…………………………………………………Confirmatory Data Analysis

DLC…………………………………………………Design Landfill Capacity

ESTs…………………………………………………Environmental Sound Technologies

HELP…………………………………………………Hydrologic Evaluation of Landfill Performance

UNBS…………………………………………………Uganda National Bureau of Statistics

UBOS…………………………………………………Uganda Bureau of Statistics

ER…………………………………………………….Effective Rainfall

CBO'S………………………………………. Community Based Organization's

MSWM…………………………………………….municipal solid waste management

HDPE…………………………………………………High density polyethylene pipe

MoWE………………………………………………ministry of water and environment

ABSTRACT

The study was to design a sanitary landfill in Kapchorwa central division to curb the problem of improper solid waste disposal. According to the study that was conducted within the municipality; it was found out that the municipality majorly had four main sources at which the solid wastes are generated; Residential wastes, Commercial wastes and Institutional wastes

Qualitative data was collected to know the characteristics of solid wastes whereas quantitative data was used to measure the waste generation rates, population size, recoverable wastes and all other phenomena that can be quantified. The sample size of the population was taken as the number of people living in Kapchorwa central division and the rate of population growth was taken equal to that of the whole district as per the 2018 population census according to the Uganda national bureau of statistics (UNBS).

The study was able to come up with suitable waste management options that would help with the problem of waste management in the area. Among others, the major ones include the following; reducing the rate of waste production, or reduce the amount generated, reduction in the negative impacts of the waste that is generated by proper waste disposal, recovery of wastes in different forms i.e. the materials recovered from the waste stream for recycling into new products, recovering materials for reuse, recovering energy by incineration, anaerobic digestion, or similar processes, reducing the volume of waste prior to disposal and disposal of residual solid waste in an environmentally sound manner, specifically in landfills.

For the recovery practice to be practicable, the government should provide market for the materials recovered from the solid wastes in order to inspire the local people to recover materials like plastics, metals, ceramics, and glass. This can be reused directly the way they are, or recycled into other valuable products.

CHAPTER ONE

INTRODUCTION

1.1 Background

Kapchorwa District is a district in the Eastern Region of Uganda. The town of Kapchorwa is the district's main municipal, administrative, and commercial center, and is the site of the district headquarters. It is also the home district of Stephen Kiprotich, men's marathon gold medalist at the 2012 Olympic Games in London. According to the Uganda Bureau of Statistics (UBOS), 2016.

The district is bordered by Kween District to the northeast and east, Sironko District to the south, and Bulambuli District to the west and northeast. The district headquarters at Kapchorwa, which means "home of friends", are located approximately 65 kilometers (40 mi), by road, northeast of Mbale, the nearest large city. The district is approximately 295 kilometers (183 mi) northeast of Kampala, the capital and largest city of Uganda. The coordinates of the district are: 01°24′N 34°27′E / 1.400°N 34.450°E, has an area of Land 354.6 km2 (136.9 sq. mi) and an Elevation 1,915 m (6,283 ft.)

Kapchorwa District is home mostly to Kalenjin peoples, including the sub-groups Sabiny, Pokot, and Nandi. They were mainly cattle keepers in the late 1960s, but that changed when their northern neighbors, the Karamojong, raided most of their cattle and displaced hundreds of people.

In 1991, the national population census estimated the district population at 48,700. The 2002 national census estimated the population at 74,300, with an annual growth rate of 4.5 percent. In 2012 according, it was estimated that the population had grown to about 114,100 and In August 2014, the national population census enumerated the population at 104,580. This is according to the Uganda census statistics.

1.2 Problem statement

In Kapchorwa town, there are poor solid waste disposal methods like open dumping which is dominant in the town due to lack of a proper disposal facility like a landfill.

This open dumping of wastes have degraded the environment through; air, soil and water pollution, and also cause serious health problems to the population as it harbors vectors like mosquitoes which cause malaria.

As World Health Organization researcher Hisashi Ogawa notes, "The management of solid waste is becoming a major public health and environmental concern in urban areas of many developing countries."

As poorer nations industrialize and become wealthier and more consumer-oriented, garbage problems usually worsen.

Uganda is facing rapid urbanization of 5.1% per annum, leading to overcrowding and the development of slums and informal settlements with poor waste management practices, Joshua Zake, 2010. Urban dwellers generally consume more resources than rural dwellers, and so generate large quantities of solid waste and sewage. Waste management in these areas is hampered by multiple land tenure system with many tenants not having a right to the land and therefore not able to manage waste domestically and also the urban authorities are overwhelmed by the sheer volumes of garbage generated (NEMA, 2004).

Kampala Capital City Authority (KCCA) acknowledges that the amount of Solid waste generated overwhelms its capacity to collect and dispose given its enormous collection costs. Out of 1,200– 1,500 tons of garbage generated per day, only 400-500 tones are collected giving a collection efficiency of only 40%. This implies that 60% of Solid waste generated daily is not properly collected and disposed which has resulted into indiscriminate disposal by the public.

(Republic of Uganda, Office of the auditor general, Value for money audit report on solid waste management in Kampala city council, 2010)

Kapchorwa like all other towns in Uganda, poor solid waste disposal has become a serious problem in this area. This is evident by the presence of open dump disposal of wastes as shown in figure.1 and this has led to several health problems to the inhabitants and also degrade the value of the environment. The poor solid waste management creates favorable conditions that harbor vectors which transmit dangerous diseases for example mosquitoes, leads to water pollution, bad odors, blockage of drainage channels, destroys the authenticity of the environment, etc.

Figure 1: open dumping of solid wastes

1.3 Project justification

At the final disposal as shown in the figure above, there is massive littering of solid waste which degrades the authenticity of the environment, soil and water pollution, etc. This is because there is no proper disposal facility within the town and there is a need for a better disposal facility which can minimize on the impacts of improper solid waste disposal. A sanitary landfill, since it is friendly to the environment and eliminates wastes completely from the vicinity of the population, as well as protecting the health of the people, is an appropriate method to address this problem. Landfills have successfully confined solid wastes away from humans vicinity and the environment for example in areas like Mbale which is among the cleanest towns in Uganda. In addition, a leachate management system can be improvised with the landfill which helps in handling the leachate generated by the waste since this has been another hazard to the environment as shown in the figure below.

Figure 2: Leachate generated by open dumping of wastes

1.3 Objectives

1.3.1 Main objective

"To design a sanitary landfill in Kapchorwa central division to curb the problem of improper solid waste disposal."

1.3.2 Specific objectives

i. Determine the amount of solid wastes generated.
ii. Determine the amount of recoverable material, (re-use and recycle).
iii. Determine the size of the landfill.
iv. Design leachate collection and storage facility.

1.4 Scope

The data content that was collected for this project was from several sources but discussing related problem of improper solid waste management in Kapchorwa district. This data covered the population size and its growth rate, waste generation rates and percentage composition, characteristics of the wastes, and then apply scientific measures to design a sanitary landfill to address the problem stated.

The project was done from December 2018 to May 2019, and the data was collected from Kapchorwa central division as the geographical area, which was our study area, and also other secondary sources.

1.5 Significance of the study

I. Educate the people about the impacts of improper solid waste management to the value of the environment.
II. Reduce the health hazards for example the spread of diseases like malaria caused by mosquitos harbored in areas of open dump disposal.
III. Understand the characteristics of the generated solid wastes in order to know the feasibility of material recovery.
IV. Know the amount of wastes generated and the possible measures of eliminating them in a way that is friendly to both the environment and the inhabitants, like landfilling.

CHAPTER TWO

LITERATURE REVIEW

2.1 The sanitary land fill

The sanitary landfill is a technique for the final disposal of solid waste in the ground that causes no nuisance or danger to public health or safety; neither does it harm the environment during its operation or after its closure. This technique uses engineering principles to confine the waste to as small an area as possible, covering it daily with layers of earth and compacting it to reduce its volume. In addition, it anticipates the problems that could be caused by the liquids and gases produced by the decomposition of organic matter. (RAMKE, H.-G., 2001).

The sanitary landfill emerged just under a century ago in the United States as the result of experiments employing heavy equipment to compact and cover waste; since then, this term has been used to refer to the site in which waste is first deposited and then covered at the end of each working day. Jorge Jaramillo, 2003.

A modern sanitary landfill can be defined as a facility designed and operated as a basic sanitation project that has sufficiently safe elements of control, and the success of which lies in the selection of the suitable site, its design, and of course, its effective and efficient operation and control.

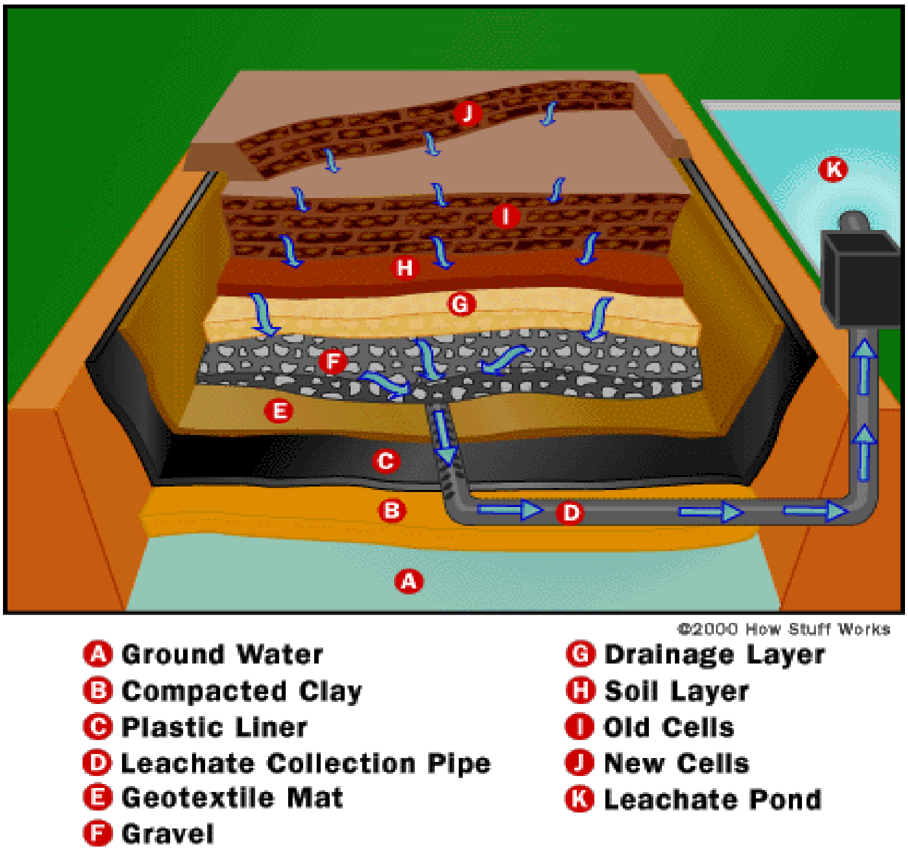


Figure 3. A sanitary landfill cross-section

2.2 Types of sanitary landfill

For the final disposal of municipal solid waste, three types of sanitary landfills could be proposed, as follows, according to **Jorge Jaramillo, 2003.**

2.2.1 Mechanized sanitary landfill

The mechanized sanitary landfill is designed for large cities and populations that produce more than 40 tons of waste daily. It involves researching into the quantity and type of waste, planning, site selection, the amount of land, the design and execution of the fill, the infrastructure required for receiving the waste and for the control of operations, the amount and management of the investments, and the operating and maintenance costs.

To operate this type of sanitary landfill, a solid waste compactor is required, as well as specialized earth-moving equipment: track-type tractor, backhoe, loader, dump truck, etc.

2.2.2 Semi-mechanized sanitary landfill

When a town needs to dispose of 16 - 40 tons daily of MSW in the sanitary landfill, it is advisable to use heavy machinery to support the manual labor, to ensure that the garbage will be thoroughly compacted, and the fill banks properly stabilized, thereby prolonging the useful life of the landfill. A farm tractor adapted with bulldozer or blade and with a scraper or roller for compacting could be suitable for operating this "semi-mechanized" landfill

2.2.3 Manual sanitary landfill

This is an adaptation of the sanitary landfill project for small communities which, in view of the quantity and type of waste produced are less than 15 t/d.

The term "manual" refers to the fact that the task of compacting and confining the waste can be carried out by a team of laborers using hand tools (labor intensive technology).

Note: The choice of sanitary landfill mostly depends on the quantity of solid wastes generated.

2.3 Construction methods for a sanitary landfill

The construction method and subsequent operation of a sanitary landfill are mainly determined by the topography of the terrain, although they also depend on the type of soil and the depth of the water table. There are two basic ways of constructing a sanitary landfill according to "guidelines for the design, construction and operation of manual sanitary landfills" by Jorge Jaramillo, 2003.

2.3.1 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

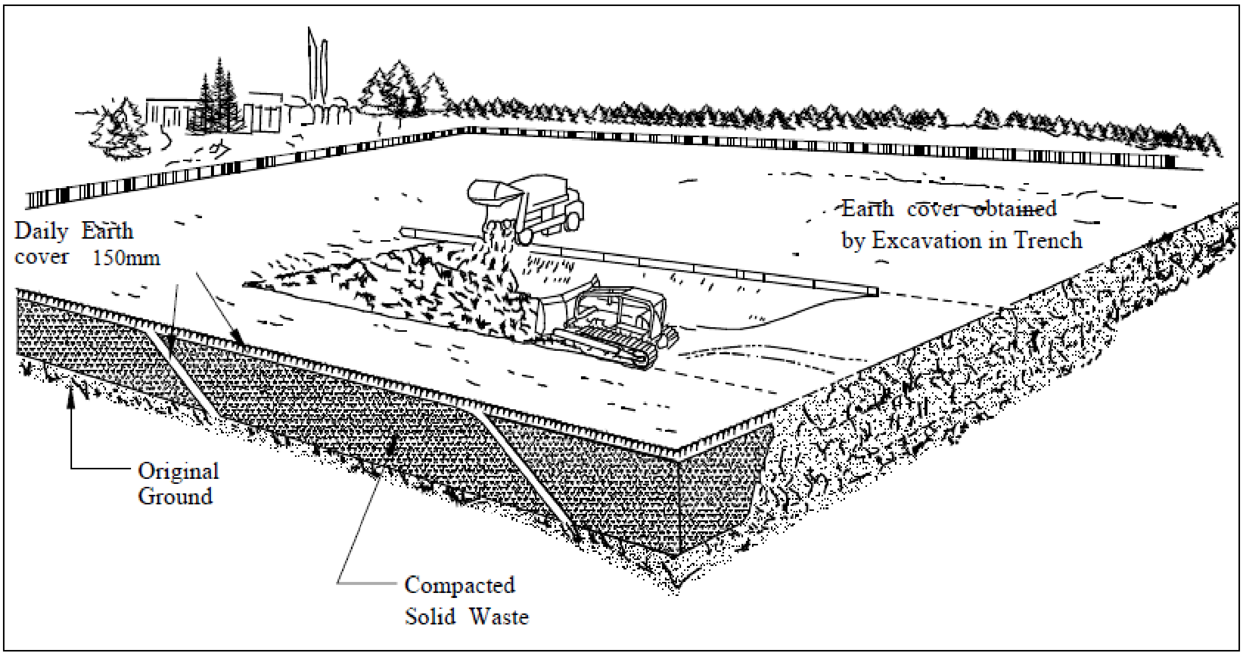


Figure 4. showing the trench method of landfilling solid waste

2.3.2 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. 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.

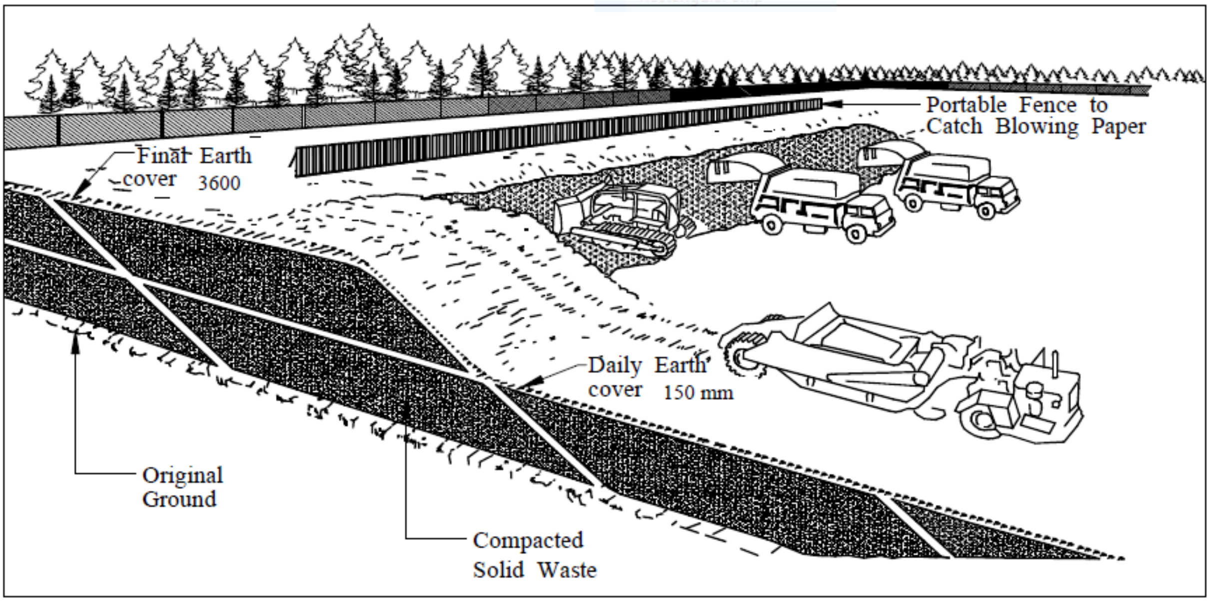


Figure 5: **Area type of landfill construction.**

2.3.3 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.

2.4 Landfill Facilities

All the individual functions must be supported and provide with the relevant facilities in order to enhance the functionality and improve on the effective 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

2.4.1 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.

2.4.2 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 and weighbridge station, etc.

2.4.3 The Supporting Facilities

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

Table 1**: The Relationship between the Functions and the Facilities in the Landfill**

FACILITIES		**FUNCTIONS**				
		Storage and treatment	Environmental protection			Land development
			Prevention of ground water pollution	Prevention of surface water pollution	Prevention of air pollution and living environment	
Operations Facilities	Solid waste retaining structure	++		+		
	Ground water drainage system		++			
	Seepage control work	+	++			
	Rainfall collection system			+		
	Leachate collection/treatment system	+	++	++		
	Daily cover facility	+	++	++	++	
	Gas treatment equipment	+			+	
Management facilities	Vehicles monitoring office	++			++	
	Environmental monitoring facility		++	++	++	+
	Administration building	+				
	Weighbridge	+				
	Machinery management	+		+	+	
Supporting Facilities	Access road	+			+	
	Workshop equipment				+	
	Notice board, gate, fence				+	
	Fire-prevention equipment				+	
	Disaster prevention equipment				++	
Post-closure land-use						++

Key: ++: Important relationship +: Mutual Relationship

2.5 Landfill designed lifespan

The target lifespan shall be the designed operational duration of the landfill site and it ranges from as low as 10yrs for small landfills to 50 years for large landfills.

The target year shall be the year the designed lifespan shall be reached, for example, the year 2020, etc.

In general, the target year for the landfill should be the same as the target year as set out in the Master Plan for solid wastes disposal.

Once the target year has been determined, considerations must be given towards finding a suitable site, carrying out financial analysis and determining the construction schedule of the landfill, (By Yachiyo Engineering Co.Ltd, 2004).

2.6 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.

a) **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:

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

II. 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.

b) **Leachate storage**

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

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

II. 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.

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

IV. 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.

c) Gravel drainage layers

I. The gravel drainage material should:

II. 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.

III. 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).

IV. 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.

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

VI. 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.

d) **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:

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

II. 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.

III. 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.

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

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

e) **Fire prevention**

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

I. 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.
II. 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.
III. Flammable solid wastes must not be stockpiled at the premises in excess of the quantity limits imposed on the license.
IV. Fire breaks should be constructed and maintained around all filled areas, stockpiles of combustibles, gas extraction equipment and site buildings.
V. Fire-fighting equipment should be installed at the site, including at flammable waste storage areas.
VI. All fire-fighting equipment should be clearly signposted and access to it must be available at all times.
VII. All fire-fighting equipment should be maintained according to a regular schedule (at minimum, weekly visual checks.
VIII. Landfill staff should be trained in all of the above fire-prevention and fire-fighting techniques.

f) **Daily Covering of waste**

I. 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.

II. Daily cover should be applied to the waste each day before the close of business.

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

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

g) **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:

I. 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)

II. Stabilize the surface of the completed part of the landfill

III. Reduce suspended sediment and contaminated runoff

IV. Minimize the escape of untreated landfill gas

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

VI. 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.

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

2.7 Site Selection Criteria

Identification of the suitability of potential landfill sites, and modifications to existing facilities, requires a comprehensive assessment of site conditions and potential impacts on the environment. It is largely agreed that successful development depends on the rational use of natural capital (World Bank, 1998). In recent years, advances have been made to measuring progress toward 'sustainable development' (Kunte et al., 1998), and in applying valuation techniques to the analysis of the environmental impacts of investment projects and public policies, both in developed and developing countries (Barbier, 1998). This includes consideration of topography, surface water, drainage, groundwater, and distance from the community the landfill will service.

The following landfill site selection criteria detail the key issues that need to be considered when identifying potential landfill sites and planning site investigations and assessing the suitability of a site for landfilling.

2.7.1 Topography

Careful consideration needs to be given to the landforms in the vicinity of the disposal site as they may influence: The type of disposal method that can be utilized, the suitability of the site for construction of service facilities, surface water drainage management, groundwater conditions, soil erosion risk, access to the site, ability to screen the site from view and the impact of winds on the site.

2.7.2 Accessibility

A landfill facility must have all means of access at all times without difficulty. Landfill development and operations can generate significant flows of heavy vehicle traffic. The following need to be considered when locating and determining access to landfills: type and number of vehicles accessing the site, types of traffic using roads adjoining landfill access road, the standard and capacity of the road network, with respect to accommodation of traffic generated by the landfill.

2.7.3 Adjacent Land Use

Adjacent existing and future land uses should be investigated to identify sensitive areas and other protected areas that are likely to be adversely impacted by landfill operations. Long term planning projections need to be considered when assessing the suitability of a site.

In order to protect sensitive areas from impacts associated with landfill operations, such as odors, noise, litter and dust, an adequate separation distance needs to be maintained between the landfill and adjacent land uses. The requirement for and extent of buffer areas should be determined on a site-specific basis. Where possible, the buffer area should be controlled by the landfill operator.

2.7.4 Participation of local authorities

The site should be selected in coordination with the environmental and health authorities, and, of course, the local planning department

2.7.5 Participation of the inhabitants

From the beginning of the selection process the public should be given the opportunity to participate, comment on the proposals made, and raise objections when necessary. In all cases it is imperative to ensure the support of the different sectors of the population during the stages of selection, design, construction, operation, maintenance and end use of the landfill.

2.7.6 Analysis of environmental impacts

Environmental impact analyses serve to anticipate the positive and negative effects that every sanitary landfill project has during its different stages: site selection, construction, operation, and closure.

The measurement of these impacts should be interdisciplinary and should be carried out on the natural components (water, soil and air), of the site and surrounding area as well as on the project-related economic and social variables.

2.7.7 Land-use plan or land regulating plan

It is essential that those responsible for site selection consult the land-use plan or regulating plan of the municipality for information such as the delineation of the urban perimeter, the growth tendency, areas of future expansion, and the areas where the construction of sanitary landfills would be permitted according to the land usage approved by the city council.

2.7.8 Location

It is advisable that the sanitary landfill be located in the direction or line of growth of the town development; however, in order to avoid disputes with the population, ideally this place would start to be populated once the useful life of the landfill has come to an end, so that the new community will have the benefit of a park or green area.

2.7.9 Other factors

(I). Land area and volume should be sufficient enough to provide landfill capacity so that the projected need can be fulfilled for several years.

(II). The landfill area having steep gradient (where stability of slope could be problematic) should not be selected.

(III). The water level in ground water table should be sufficient below the base of any excavation to enable landfill development.

(IV). Public & private irrigation water supply wells should be well away from the boundaries of landfill site because these supply wells will be at risk of contamination.

(V). Landfill area should not be very close to significant water bodies (water courses or dams). There will be the risk of contamination of water bodies, which can be hazardous for aquatic life.

(VI). No major power transmission or other infrastructure like sewers, water supply lines should be crossing through landfill developmental area.

(VII). Landscaping and protective shelf should be included in the design so that to minimize the visibility of operations.

(VIII). Unstable areas that have significant seismic risk which could cause destruction of berms are not recommended for landfill site.

(IX). There should not be fault lines and significantly fractured geological structure. These fault lines can allow the unpredictable movement of gas within 500 meters of perimeter of proposed landfill development.

(X). Groundwater quality should not be disturbed during the site developmental phase. There should be monitoring facilities at site in order to ensure that ground water quality is maintained.

(XI). In areas under the laws of concerned municipality it should be responsibility of municipality to identify landfill site and handover to operators for operations.

(XII). Selection of landfill site should be based upon the examination of environmental issues.

(XIII). The landfill site should be near the wastes recycling facility otherwise, the waste recycling facility should be planned as integral part of landfill site.

(XIV). Biomedical wastes should be disposed of in accordance with guidelines issued by Ministry Of Health, Government of Uganda.

(XV). Landfill site should be away from airports. There is need of approval of airbase authorities like civil aviation authorities of government of Pakistan for setting up of landfill site in case if site is to be locating within ten kilometer of an airport boundary.

2.8 Plans associated with landfill projects include:

I. A base map showing existing site conditions with contour intervals of 1 foot to 5 feet, and a scale of 1 inch equal to 50 feet to 1 inch equal to 200 feet.
II. A site preparation plan designing fill and stockpile areas, and site facilities.
III. A development plan showing initial excavated and final completed contours in filling areas.
IV. Construction details illustrating site facilities.
V. Cross sections illustrating phased development of the landfill at several interim points.
VI. A completed site plan includes the final site landscaping and other improvements.

2.9 Site layout

The site layout must be designed with the disposal site's closure and end-use closely in mind. The extent and shape of the buffer zone will also influence the site layout and the eventual design. In particular, the end-use may decide the final shape or contours of a landfill, and this may influence the site layout and the Operating Plan (by Jorge Jaramillo, 2003).

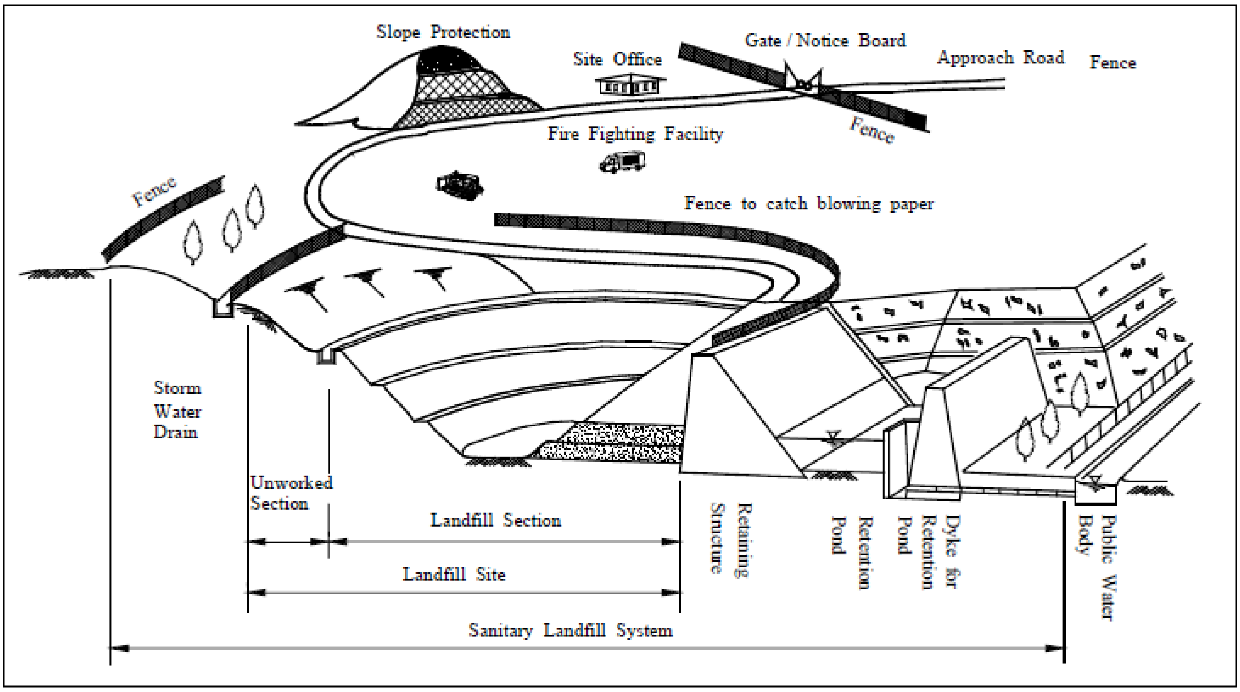


Figure 6: **The site layout of landfill facilities**

2.10 Future use of the sanitary landfill

The future use or "end use" of a sanitary landfill depends on several factors: the climate, location with respect to the urban area, its distance from inhabited areas, surface area, and construction characteristics. These "construction characteristics" refer to the final layout of the landfill, the height and degree of compacting, and also an important factor which is the economic capacity of the town's inhabitants.

The site of a closed sanitary landfill is ideal for developing scenic and social programs such as a park, a sports field or a green area.

The landfill surface is not recommended for buildings, houses, schools, or any other heavy infrastructure, because it does not have the capacity to support heavy structures; besides, there could be problems due to sinking and the production of gases.

To re-create the natural landscape, grass and plants with short roots should be planted. In many cases, after the final earth cover has been applied, grass grows back spontaneously.

2.11 Differential sinking and settling.

In the sanitary landfill, sinking (uniform settling or faults) occurs. This is the easiest problem to spot, and also the easiest to control with good compaction.

Differential settling also occurs at the surface, and in time this gives rise to depressions and cracks of different sizes, causing ponding of water and an increase of leachates and gases. These problems depend on the layout and height of the landfill, the type of waste buried, the degree of compaction, and volume of rainfall in the area (by Jorge Jaramillo, 2003).

2.12 Advantages and disadvantages of a sanitary landfill.

Advantages

(I). The initial capital investment is lower than that required to establish incineration plants or composting facilities for waste treatment.

(II). It has lower operating and maintenance expenses than treatment methods.

(III). A sanitary landfill is a complete and definitive method, given its capacity to receive every kind of MSW.

(IV). It creates employment for unskilled labor, which is available in abundance in developing countries.

(V). Methane gas can be collected in sanitary landfills that receive more than 500 tons/day, and this gas can be an alternative source of energy for some cities.

(VI). Its location can be as close to the urban area as the existence of available sites permits, which reduces hauling costs and facilitates supervision by the community.

(VII). It allows lands considered unproductive or marginal to be recuperated, making them useful for constructing parks, recreational facilities, green areas, etc.

(VIII). A sanitary landfill can start operating in a short time as a waste elimination method.

(IX). It is considered flexible because it can receive greater additional quantities of waste with a small increase in personnel.

Disadvantages

(I). The acquisition of the terrain is often a problem due to local inhabitants' opposition to the selected site. This is because of various reasons like: Lack of knowledge of the sanitary landfill technique, uncontrolled open dumping, and Citizens' evident distrust of local administrations to guarantee sustainability of the work, and legal problems regarding land registration.

(II). The rapid process of urban growth that limits the amount of land available and makes it more expensive, causing the sanitary landfill to be located at a distance from the town.

(III). The finished landfill is not recommended for building homes, schools, etc. restricting the future use of the landfilled area.

(IV). The restriction against building heavy infrastructure because of excessive settling and sinking after the landfill is finished.

(V). It can cause a long term environmental impact if the necessary precautions are not taken in the selection of the site and if mitigation measures are not applied. In the case of large sanitary landfills, it is advisable to analyze the effects of vehicular traffic, in particular the trucks carrying the waste on the roads that converge on the site and that produce dust, noise and windblown litter. In the immediate neighborhood the impact is produced by the liquids, gases and bad odors that can emanate from the landfill.

(VI). The properties or land surrounding the sanitary landfill may be devalued.

(VII). Usually it cannot receive hazardous waste.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

Methodology is a set of methods and principles for data collection and analysis in order to meet the desired objectives of the project.

3.1 Basic requirements during research

3.1.1 Quality control

Quality control activities (detection/monitoring and action) were ensured during and after data collection. Detection or monitoring can take the form of direct staff observation during site visits, conference calls, or regular and frequent reviews of data reports to identify inconsistencies, extreme values or invalid codes.

Quality control helped in identifying the required responses, or 'actions' necessary to correct faulty data collection practices and also minimize future occurrences.

3.1.2 Ethical values

Research ethics are important for a number of reasons. They promote the aims of research, such as expanding knowledge. They support the values required for collaborative work, such as mutual respect and fairness. This is essential because scientific research depends on collaboration between researchers and groups. Ethical value portrayed during our research include; minimizing the risk of harm, obtaining informed consent, protecting anonymity and confidentiality, avoiding deceptive practices, and providing the right to withdraw.

3.1.3 Environmental values

One of the objectives of this is to ensure that all the activities involved during the research do not deteriorate the environment. This was achieved by carefully handling wastes not to expose them to the environment and cleaning any spillage which can pollute the environment.

3.2 Research design.

Qualitative research is a scientific method of observation to gather non-numerical data. This type of research "refers to the meanings, concepts definitions, characteristics, metaphors, symbols, and description of things" and not to their "counts or measures. Quantitative research is the systematic empirical investigation of observable phenomena via statistical, mathematical, or computerized techniques.

In this research, qualitative data was collected to know the characteristics of solid wastes whereas quantitative data was used to measure the waste generation rates, population size, recoverable wastes and all other phenomena that can be quantified.

3.3 Sample size

The sample size of the population was taken as the number of people living in Kapchorwa central division and the rate of population growth was taken equal to that of the whole district as per the 2018 population census according to the Uganda national bureau of statistics (UNBS).

3.4 Data collection and analysis

Primary data sources include information collected and processed directly from site, such as observations, surveys, interviews, and focus groups.

Secondary data sources include information retrieved from pre-existing sources such as research articles, Internet or library searches. Pre-existing data may also include examining existing records and data within the program such as publications and training materials, financial records, student/client data, and performance reviews of staff, etc.

The data was collected from both primary and secondary sources.

Data analysis is a process of inspecting, cleansing, transforming, and modeling data with the goal of discovering useful information, informing conclusions, and supporting decision-making.

In statistical applications, data analysis was divided into descriptive statistics, exploratory data analysis (EDA), and confirmatory data analysis (CDA). EDA focuses on understanding the message in the data and discovering new features in the data may result in additional data cleaning or additional requests for data. CDA focuses on confirming or falsifying existing hypotheses. Predictive analytics focuses on application of statistical models for predictive forecasting or classification.

3.5 Data presentation

The data was represented with graphs, pie-charts, tables and figures. Presentation of data was done using micro soft PowerPoint.

3.6 Amount of wastes generated /or Waste generation rate.

The waste generation rate varies with the social economic status of the area which is based on the lifestyle, population size, urbanization and income levels of the population. The waste generation rates increase with the increase in per capita income from low income levels to the high income per capita level. People who earn less spend less and they majorly spent on basic needs, while people who earn more spend more especially on luxurious goods hence generate more wastes.

The amount of wastes was determined by calculating the total wastes generated from different areas i.e. schools, hospitals, offices, shops, residential places, street sweeping, prisons, etc.

Since most of the inhabitants use collective/shared collection methods for temporal storage of solid wastes, data related to quantities of solid waste generation was collected from the municipal council department of solid waste management, or Uganda bureau of statistics (UBOS). This was used to determine the total amount of wastes that was generated within this area.

3.7 Recoverable materials

The supply of raw material is not inexhaustible and the recovery of material regarded as waste was essential for the conservation of natural resources. Consequently, reuse, recycling, and productive use of wastes are important activities in the integrated management of solid wastes. These activities are mainly aimed at reducing the volume of waste to be landfilled and also increase its economic value.

3.7.1 Reuse

Reuse is a first level of waste recovery and involves the direct use of a product or material in its original forms or functions. An example is the reuse of containers, bottles, plastics, Jars, tin cans, cardboard boxes, and wooden boxes.

3.7.2 Recycling

Waste recycling refers to external recovery reuse or reprocessing of post-consumer and post product waste and is an important part of waste management hierarchy (Johnston et al, .2000). The reuse comprises the recovery of items to be used again, in the same state but may require cleaning and refurbishing. (Hui et al, 2006).

The solid wastes i.e. broken glass, paper, cardboard, metal, plastics, etc. becomes the raw material for an industrial process to manufacture new products of similar composition.

Recovery and recycling of municipal solid wastes shall be achieved by manual solid waste segregation which aims at separating the different components of solid wastes for easy handling, reuse and recycling processes.

The amount of recoverable materials shall be measured and reduced from the total amount of solid wastes produced, and this will give the quantity of solid waste ready to be landfilled.

3.8 Determine the size of the landfill

Designed Landfill Capacity (DLC) which 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, will be used to determine the physical size of the landfill and the total area required for the construction of a sanitary landfill in Kapchorwa central division. This will also help in calculating the size of landfill phases required

3.9 Design leachate collection and storage facility.

The natural decomposition or putrefaction of garbage produces a foul-smelling black liquid, known as leached or percolated liquid that looks like domestic water waste, but much more concentrated. This liquid must be managed appropriately to prevent hazards that might raise when this liquid is exposed to the environment without proper treatment. A pipe collection system must be improvised especially for biodegradable wastes.

The volume of leachate depends basically on the rainfall. Leachate is produced not only by runoff but also by rainfall in the area of the landfill, which increases the quantity, either by direct precipitation on the waste deposited or by increasing the amount of filtration through cracks in the terrain.

For this project, a herringbone shaped pipe system of drainage, and a storage facility with size based on the volume of leachate generated, shall be designed using AutoCAD.

CHAPTER FOUR

RESULTS

4.1 Sources and the Types of Solid Waste Generated.

According to the study that was conducted within the municipality; it was found out that the municipality majorly had three main sources at which the solid wastes are generated. A summary of them is illustrated in table 4.1 below with their respective locations where they are generated and the types of wastes in each source.

Table 2: **The sources, location and types of solid wastes generated in Kapchorwa central division**

Source	Typical Facilities, Activities, or locations where wastes are generated	Types of Solid Wastes
Residential wastes	Single family and multifamily detached dwellings, low-medium and high-rise apartments, etc.	Food wastes, paper cardboard, plastics, textiles, yard waste, wood, glass, tin cans, aluminum, other metals, ashes, street leaves, special wastes (including bulking items, consumer electronics, white goods, yard wastes collected separately, batteries, oil and tires), house hold hazardous wastes
Commercial wastes	Stores, restaurants, markets, office buildings, hotels, motels, print shops, service stations, auto repair shops, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes (see above), hazardous waste, etc.
Institutional wastes	Schools, hospitals, prisons, governmental centers, healthcare units and tertiary institutions	As in Commercial

4.2 Amount of wastes generated in the study area

According to (A global review of solid waste management report by World Bank, 2012), Uganda was generating solid wastes at a rate of 0.34kg/capita/day. It also shows a generation projection rate of 0.65kg/capita/day in the year 2025. Furthermore, UBOS 2018 gives a generation rate between 0.5-1.1kg/capita/day of solid wastes within Kampala capital city.

In this project, a solid waste generation rate of 0.65kg/capita/day was considered since there was inadequate published data about solid waste generation for the study area.

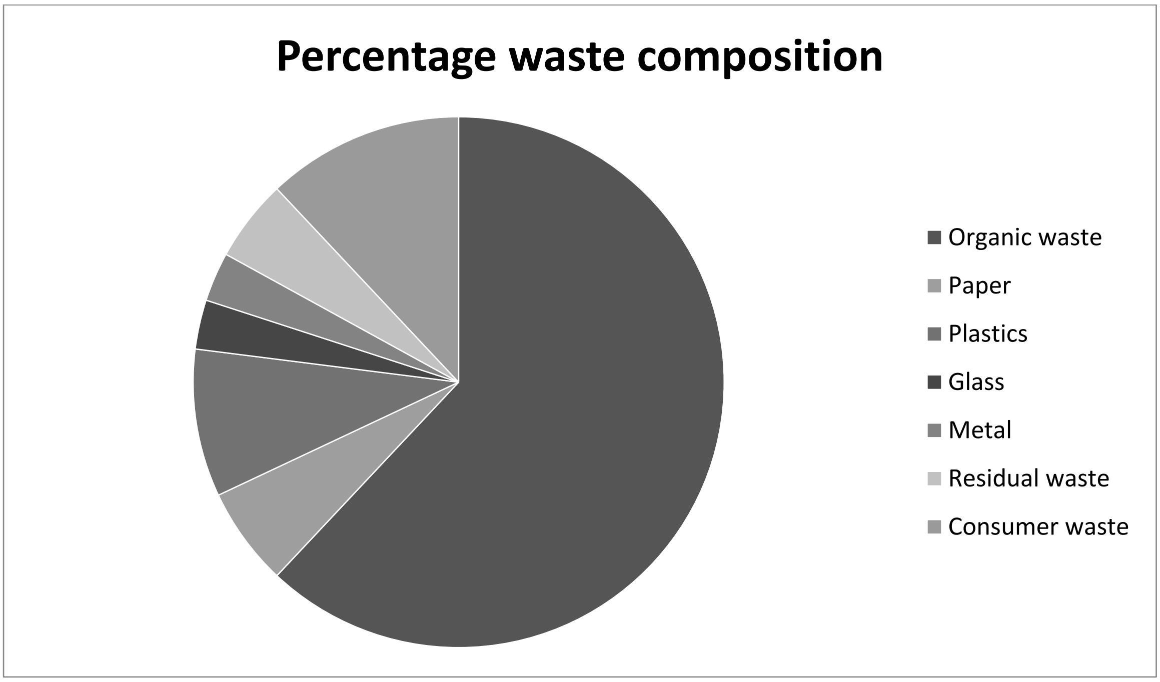
4.2.1 The waste quantities and composition

Weighing of solid waste or percentage composition studies had not been done except for weight estimates through use of capacity of garbage collecting tractor. This data couldn't be dependable and therefore the national statistics was considered. According to the UBOS 2016, the percentage composition of solid wastes was as shown in the table below.

Table 3: **The solid waste percentage composition**

S/N	Composition	Percentage (%)
1	Organic content	62
2	paper	6
3	plastics	9
4	glass	3
5	metal	3
6	Residual waste e.g. ash, inerts, dirt, sweepings	5
7	Consumer wastes e.g. ceramics, household appliances, textiles, rubber, electronics, leather, multi material packaging, etc.	12

Figure 7**: Pie-chart showing Percentage waste composition**



4.2.2 Amount of wastes generated per day

According to UBOS 2018, the population of Kapchorwa central division, which is our study area, was estimated to be 12850 people. The generation rate taken as 0.65kg/capita/day, the total solid wastes generated can be calculated as follows;

W = rate x population

W = 0.65 x 12850 = **8,352.5kg/day** which is approximately **8.4 tons/day**

Table 4. Amount of wastes in kilograms per day

S/N	material	Percentage, p (%)	Quantities q(kg/day) =(p/100) x 8352.5kg/day
1	Organic content	62	5178.55
2	paper	6	501.15
3	plastics	9	751.725
4	glass	3	250.575
5	metals	3	250.575
6	Residual wastes	5	417.625
7	Consumer wastes	12	1002.3
Total		**100%**	**8352.5kg/day**

Therefore, the amount of wastes generated was found to be **8,352.5kg/day** from a generation rate of **0.65kg/capita/day**.

4.3 The recoverable amount of waste.

In order to reduce the amount of solid waste to be landfilled, material recovery was employed to put into use those materials that could be re-used, and recycled to different products.

The materials that were recovered in this project are the plastics, metals, paper, glass, and consumer wastes. This amounts to a percentage of **33%** (**2756.325kg/day**) of the wastes recovered for reuse and recycling, and a percentage of **67%** (**5596.175kg/day**) left to be landfilled.

From the above, recovery of materials successfully reduced the wastes left to be landfilled; hence our second objective achieved.

4.3.1 Ways how waste materials can be reused;

- Reuse durable mugs, glasses, dishware and silverware rather than eating from disposable paper or plastic containers.
- Reuse a cloth sack to carry your groceries each time you shop.
- Reuse old tires for swings or playground obstacle courses.
- Have a yard or garage sale to sell items that you no longer want. If you don't want to sell these things, donate them to an organization or group that can reuse or sell them.

The waste materials recycled in this project are mainly plastics, ceramics, paper, electronics, appliances, and metals. Since they can act as raw materials for the manufacture of new products of the same material, these materials were recovered back to the economy.

4.4 Size of landfill (volume and area)

The physical size of the landfill was determined by the design landfill capacity in order to get the area required to construct the landfill. The anticipated design life of the landfill was 30years.

4.4.1 Population projection for Kapchorwa central division

The population of Kapchorwa central division as per 2018 UBOS was 12850 people, a population growth rate of 2.9%, and fertility rate of 7.8% and an average of 7 children per family.

The year-by-year population projections for Kapchorwa central division was then computed by applying the basic equation i.e. the mathematical method relating to geometric growth, that is, to biological populations in expansion, for which a growth rate is assumed to be constant. The equation was:

$$P_n = P_o (1 + GR)^n$$

Where:

P_n is the projected population after the nth year from the initial year.

P_o is the initial population in the initial year i.e. **2019**

GR is the population growth rate, **GR**=**2.9**% (UBOS 2018)

n is the number of years the landfill will operate or it's the design life of the landfill.

(n = 30yrs)

To project, for example, the population from the year 2019 to 2049,

$pop_{\mathbf{2049}}$ = Actual pop_{2019} $(1 + \text{growth rate})^n$

The population of 2019 can be calculated as;

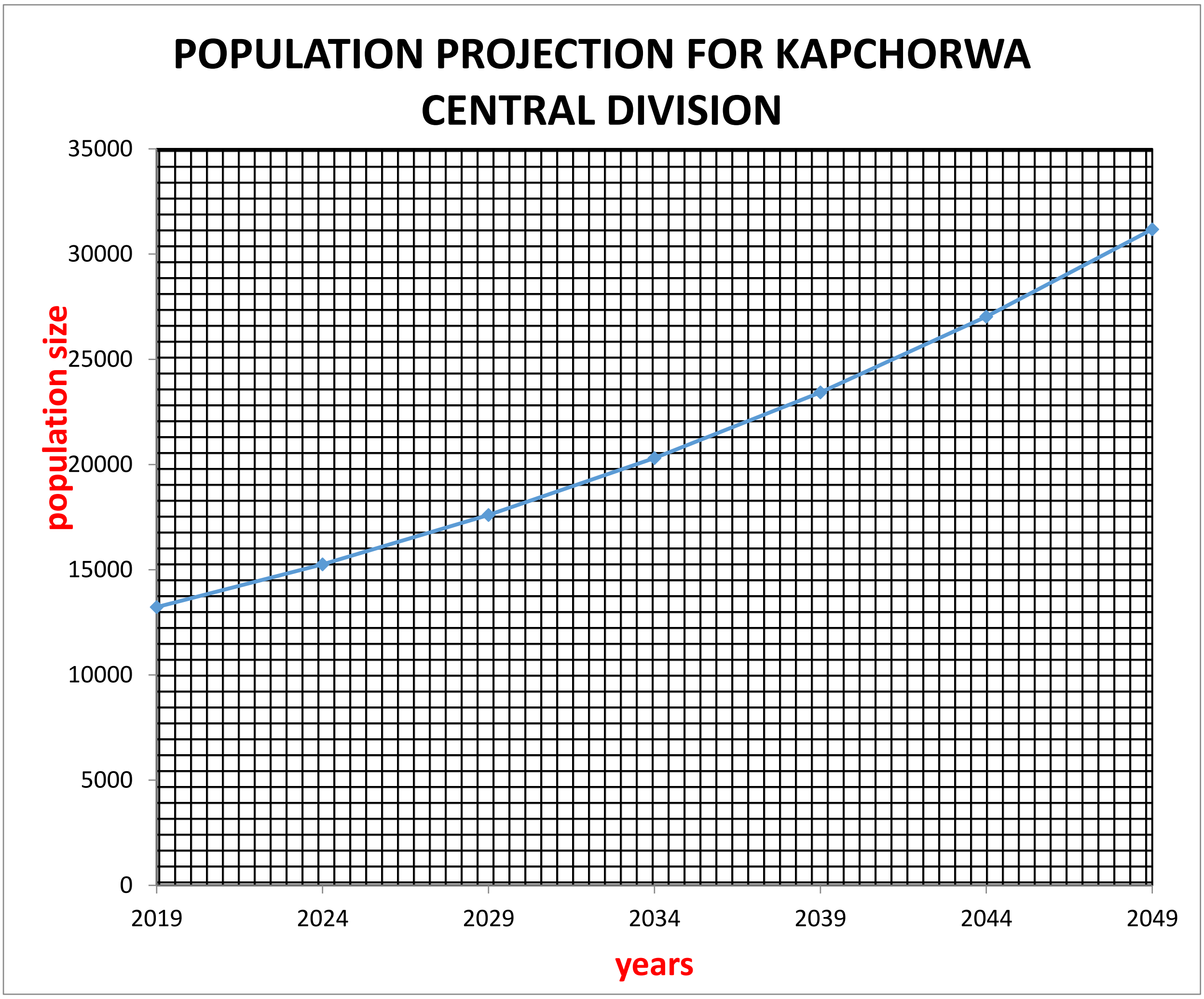
$P_{2019} = pop_{2018}\,(1+ 0.029)^1 = 12850(1.029)^1$ =**13223 people**

Therefore, the population projection of the design year is calculated from;

$P_{2049} = 13223\ (1 + 0.029)^{30}$ = **31174 people** by the design year.

The population projection for the years 2019 till the design year of 2049 are therefore summarized in the graph below with the growth rate taken as constant for all the years.

Figure 8: The graph of population projection of Kapchorwa central division



4.4.2 Waste generation projection for the design population

The quantity of waste was obtained using the design population in order to know the amount of waste at the design life of the landfill. The estimate was then carried out using the following formula;

$WG = P_n * R * 365 * D.L$

Where; D.L is the Design life of the landfill

P_n is the design population

R is the waste generation rate

WG =31174 * 0.65 * 365 * 30 = **221,880,945 kg** produced by 2049

From clause 4.3, 67% of these waste is to be landfilled, therefore the amount of wastes to be landfilled by the design life of the landfill is got from;

Wastes to be landfilled WL= (67/100)* 221,880,945 = **148,660,233.2 kg**

4.4.3 Landfill design criteria

a. Design population of 2049 = 31174 people
b. Total quantity of wastes generated WG= **221,880,945** kg by 2049
c. Waste generation rate = 0.65kg/capita/day
d. Amount of wastes landfilled by the design year WL= **148,660,233.2** kg
e. Aboveground side slopes of 4H : 1V, H-horizontal, V-vertical
f. Maximum of 3H : 1V for below ground side slopes
g. Apparent waste density ƒ = 500kg/m^3 or 0.5tonnes/m^3
h. Minimum of 1meter thickness of vegetable final cover.
i. Factor of increase in the additional area required for penetration roads, border setback areas, control building and sanitary facilities, maneuvering yard, etc. shall be taken between 20-40% of the area to be landfilled by the design year.
j. Thickness of liner layer including leachate collection layer is taken as approximately 1m, and a 1.0m thickness of cover system.
k. Adopt a height of fill to be 8m

4.4.4 Volume of waste, volume of daily cover, and the volume required for the components of cover and liner system.

- **The volume of wastes**, V_m is calculated from V_m = WL/ƒ = 148,660,233.2 /500

V_m = **297,320.466 m^3**

- **Total volume of daily cover** (V_{dc}) = 10% of the volume of waste to be landfilled.

V_{dc} = (10/100) * 297,320.466 = **29,732.047 m^3**

- **Volume required for components of cover and liner layers**, having thickness of cover as 1.0m and 1.5m for liner layer including a leachate collection layer, is calculated from;

$V_C = K V_m$ where K is equal to 0.25 for landfills with height up to 10m according to "The Technical Guideline for Sanitary Landfill, Design and Operation (Revised Draft, 2004)"

V_c = 0.25 * 297,320.466 = **74,330.117 m^3**

Volume of landfill or Landfill capacity C1 = $V_m + V_{dm} + V_c$

= **297,320.466** + **29,732.047** + **74,330.117**

C1 = 401,382.63 m^3

4.4.5 Area required for the landfill and other facilities

- Area required for the landfill A1 = volume of landfill / height of fill

Taking the height of the landfill as 8m, A1 = 401,382.63 /8

A1 = 50,172.829 m^2

Plan dimensions of the area to be occupied by the wastes is **255m x 200m** giving an acquired area of **51,000m^2**

- Additional area A2 required for penetration roads, border setback areas, control building and sanitary facilities, maneuvering yard, etc. has been taken as 30% of the area to be landfilled for the design life.

A2 = (30/100) * 50,172.829

A2 = 15,051.849 m^2

Therefore, the total area required for the landfill and its associated facilities is given by; A = A1 + A2 = **50,172.829 + 15,051.849**

A = 65,224.678 m^2

Considerations;

- Likely shape of the landfill = Rectangular in plan, primarily below ground level, partially above ground level.
- Approximate plan dimensions considered are **300m x 218m,** and the new area acquired is **65,400 m^2**.

From the above calculations, the volume of the landfill has been established to be **401,382.63 m^3,** which is our landfill capacity. From the landfill capacity, the area required for the landfill and its other supporting facilities, considering a landfill height of 8m, has been calculated to be **65,224.678 m^2.**

4.4.6 Design of landfill phases

Actual design life of the landfill = 30years

Estimated duration of one phase =2.5 years

Number of phases = design life/duration of a single phase = 30/2.5 = 12 phases.

NOTE: Each phase extends from the base to the final cover.

Volume of one phase = landfill capacity/number of phases = 401,382.63 /12

Volume of each phase = 33,448.553 m^3

Plan area of one phase = volume of one phase/landfill height = 33,448.553 /8

= **4,181.069 m^2**

Approximate dimension of each phase is **85m x 50m**, giving an area of **4250 m^2**

Total area occupied by all phases is equal to **4250 x 12, =51,000m^2**

4.5 Landfill liner design

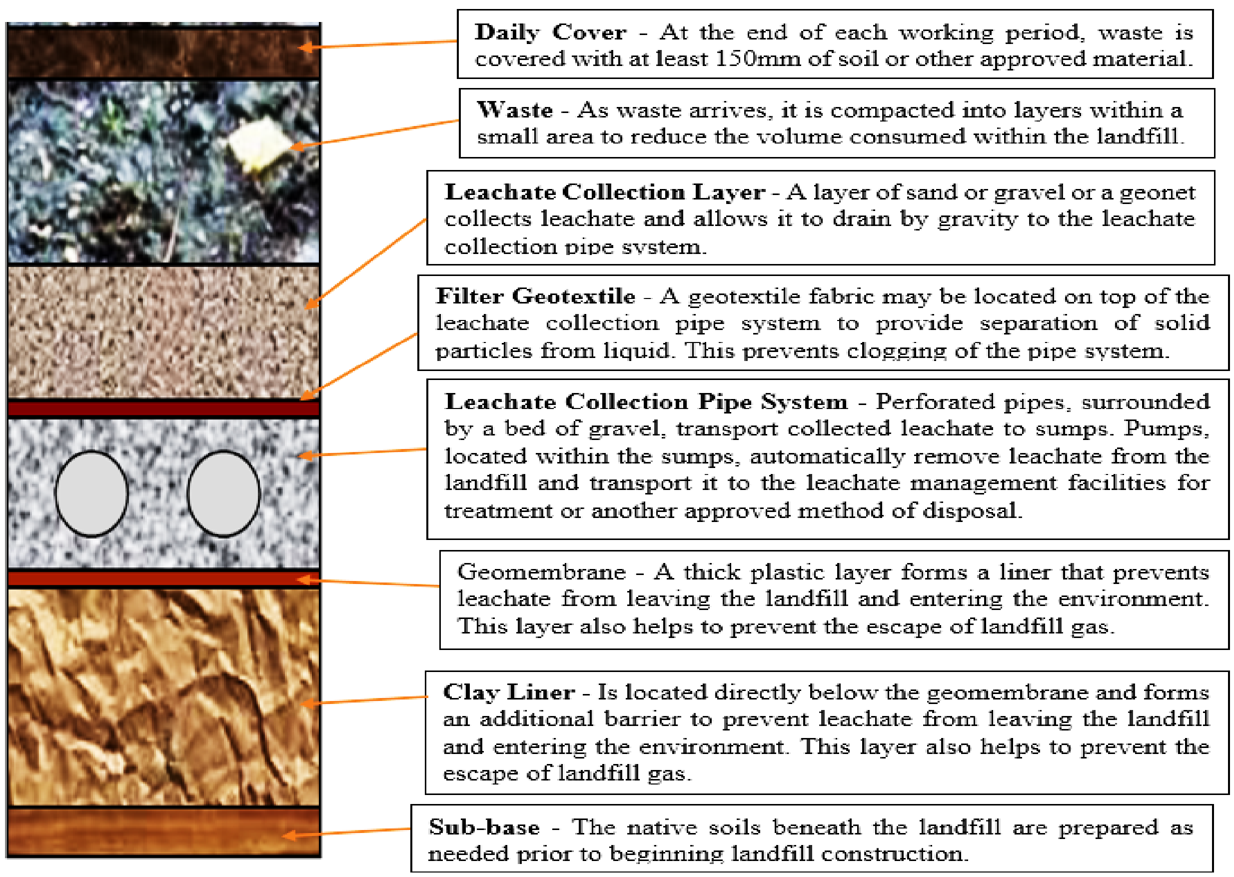
4.5.1 Bottom Liner system design

A composite liner system was considered due to its effectiveness to limit leachate migration with a geo-membrane in conjunction with a clay liner.

Summary specifications for the landfill bottom layers

- A low-permeability clay material compacted to achieve a specified minimum permeability. Base and sidewall mineral layer with hydraulic conductivity less than or equal to $1x10^{-7}$m/s. This is achieved by using a 600mm thick layer of clay, compacted in 150mm layers.
- Landfill base = 150mm
- Clay/amended soil with low permeability ($1x10^{-7}$) =600mm
- HDPE geo-membrane or synthetic flexible membrane =1.5mm think
- Leachate collection layer (blanket) =300mm

Figure 9: A composite liner system for the landfill



All medium and large landfills should have a composite liner system consisting of the following components as a minimum: sub base, clay liner, geomembrane, and a drainage layer/leachate collection system.

Source: "Territory, N. & Protection, E., 2013. Guidelines for the Siting, Design and Management of Solid Waste Disposal Sites In the Northern Territory. ,(January)."

A very clear illustration of the landfill liner layers below the compacted wastes can be seen from **appendix 1.**

4.5.2 Landfill liner layers above the wastes

A 1m final cover was considered to cover the waste and allow vegetation growth to cover the landfill. The layer consisted of 500mm clay sealing soil of a low permeability just above the wastes, a 300mm sand soil as drainage layer for water, and a 1000mm vegetable soil layer at the surface to support vegetation growth.

The final landfill liner layers above the compacted waste are clearly illustrated in **appendix 2.**

4.5.3 Final Cover Design

The final cover that will be placed on the landfill has been designed to meet the following objectives:

- Prevent disturbance of the waste;
- Support vegetation for landfill rehabilitation; and
- Allow at least 150 mm/a controlled infiltration of precipitation.

The overall final cover thickness of 1.0 m of un-compacted native soil, will serve to prevent disturbance of waste in the long term. The final cover will support vegetation, to prevent erosion and allow the landfill to be integrated with the surrounding area as part of the rehabilitation of the site.

Figure 10: Summary of the landfill liner system

Parameter	Specification
Re-cultivation Soil Layer	1000mm
Sand Drain/ drainage layer for water	300mm
Clay sealing layer with low permeability	600mm
Leachate collection layer (blanket)	300mm
Leachate collection pipe system	500mm
HDPE geo-membrane or synthetic flexible membrane	1.5mm think
Clay/amended soil with low permeability ($1x10^{-7}$)	600mm
Landfill base	150mm

4.6 Leachate quantities, Leachate collection design, Storage tank design, and Treatment plant

4.6.1 Quantities of leachate generated from the landfill

The leachate quantity was calculated from the water balance equation which considers the water inflow and outflow studies.

According to EPA (2000), knowledge of the likely leachate generation of a landfill is a prerequisite to the planning of a leachate management strategy. An understanding of the likely potential for leachate generation is essential at the conceptual design stage. Water balances are used to assess likely leachate generation volumes.

Parameters used include waste volumes, input rates and absorptive capacity, effective and total rainfall, infiltration and other site parameters.

The calculation was of the form: $Lo = [\mathbf{ER}(A) + LW + IRCA(\mathbf{A}) - (aW)]$

Where

Lo = leachate produced (m^3)

ER = Effective rainfall (use actual rainfall)

A = Area of the landfill (m^2)

LW = liquid waste (also includes excess water from sludge's) (m^3)

IRCA = Infiltration through Restored and Capped Areas (m)

a = Absorptive capacity of waste (m^3/t)

W = Weight of waste deposited (t)

The effective rainfall for Kapchorwa ranges between 1500-2500mm per year (Statistical Abstract for Kapchorwa) Adopting **2500mm** for the design.

The area of the landfill calculated above = **50,172.829 m^2**

LW = **0**, Council Directive on the landfill of waste (99/31/EC) requires Member States to prohibit the acceptance of liquid waste, meaning any waste in liquid form including waste waters but excluding sludge, to landfill.

IRCA = According to Knox (1991), it is assumed that all the Actual Rainfall will infiltrate into the waste. In areas that have been restored an infiltration rate in the range 2-10% of ER is considered in a worst case scenario for a geomembrane or geo-synthetic clay liner cap.

Thus considering 10% of the annual rainfall gives IRCA = 0.1 * 2500 =**250mm.**

a = Absorptive capacity of waste (m^3/t), this is the amount of water that can be absorbed without generating leachate and it depends on the type of waste, its initial moisture content and the density to which it is compacted. It can obtain from the figure below.

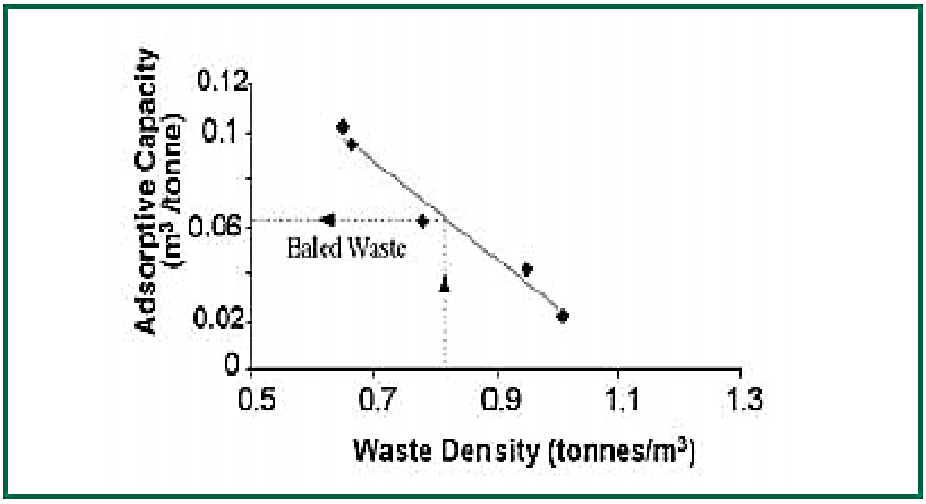


Figure 11: capacity of the waste. Source: (EPA Ireland, 2000)

From the figure above, considering a waste compaction density of 0.5tons/m3, it can be approximated that the adsorptive capacity of the waste is **0.13m³/ton**s

W = Weight of waste deposited into the landfill (t) = **148,660,233.2 kg / 1000 = 148,660.233 tons**

Thus from the water balance equation above, amount of leachate generated after the whole landfill has been occupied with waste will be;

Lo= [2.5m * (50,172.829m²) + 0+0.25m * 50,172.829m²− (0.13m³/t x 148,660.233tons)]

Lo = 118,649.450 m³ of leachate produced from the whole landfill area covered with wastes after the design life of the landfill.

Estimated volume of leachate per day

Volume of leachate per day = **118,649.450m³** / (30(design life) * 365) = **10.836m³/day**

4.6.2 Leachate storage tank design

The volume of the tank was based on the volume of leachate generated per day.

Volume of tank = (volume discharged * detention time)

With an assumed depth of the leachate tank and the volume of leachate already known;

Area of the tank $A = V/d$

Where:

A is the area of tank (m), V is the volume of tank (m) and d is the assumed depth of tank (m).

Volume of the tank V = volume of leachate produced * detention time

Assuming a detention time of about 2days,

V= **$10.836m^3$/day * 2 days;** **V= $21.672m^3$**

Adding a volume freeboard space of about 10% of the volume of the tank to cater for overflow and critical discharge conditions, V = 1.1 * 21.672

V = $23.839m^3$

Assuming a tank depth of 3m,

Surface area of the tank **A**= **$23.839m^3$ / 3m**

A = $7.946m^2$

Tank width = 2500mm, tank length = 3200mm, and tank depth of 3000mm

Table 5. Summary for the design of a leachate collection tank

Description	**Calculation**	**Value**
Detention time	Assumed	2days
Volume of the tank	V= **$10.836m^3$/day * 2**	**V= $21.672m^3$**
Volume plus freeboard i.e. 10%**V**	V = 1.1 * **$21.672m^3$**	**V = $23.839m^3$**
Depth	Assumed	3m
Area	**A**= **$23.839m^3$ / 3m**	**A = $7.946m^2$**
Width	Assumed	2.5m
Length	Assumed	3.2m
Design plan area	2.5 * 3.2	**A= $8m^2$**
Design tank volume	(2.5*3.2*3) design dimensions	**V = $24m^3$**

Therefore, the leachate storage facility has been successfully designed having dimensions of 2.5 * 3.2 * 3m, and an area of **8m²** (2.5 * 3.2), with an overall volume of **24m³.**

4.6.3 Design of the Leachate Collection pipe network System

The following are the design considerations that were followed;

a) A geo-membrane must be placed on top of the clay surface.

b) After the barriers have been installed, slotted pipes are placed on top of the geo-membrane. The leachate collection pipes are to have a diameter of about 300 mm, and the perforations usually cover about 50% of the pipe's circumference.

c) The collection lateral pipes are placed about 15m apart, collection header pipes 40m apart, and are covered with a drainage layer of sand and gravel. As a precaution against clogging of the pipe perforations, a fabric filter can be placed on top of the drainage layer.

d) The separation between the pipes will control the amount of leachate that will accumulate at the bottom of the fill.

e) In a typical operation, the layer of coarse sand and gravel without limestone (to reduce the rapid production of carbon dioxide); grain size ≥ 16 - 32 mm and should be about **500mm** thick and is placed on top of the collection pipes a few weeks before the first load of waste is discharged on the cell. It is advisable not to compact the first layer of waste in order to protect the integrity of the piping network.

f) The slope of the unit should be on the order of 1% to 3% in order to promote the migration of leachate toward the collection points. The designs of these facilities should promote drainage by gravity.

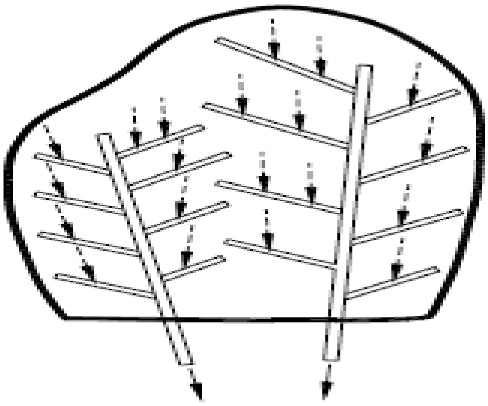
Table 6: Summary of the Design Specifications for the leachate collection system;

Particular areas	Specification
Drainage material	Coarse material, without limestone (calcium carbonate), grain size ≥ 16 – 32mm and layer thickness of about 500mm
Drainage layer	thickness 300mm
Drain Pipes	Diameter 300mm for header pipes and Diameter 150 mm for lateral pipes, made of HDPE
Manholes	Diameter 1000mm
Cross slope	≥ 3%
Longitudinal slope	≥ 1%
Drain Pipes Spacing	≥ 30 m, take 40m
lateral Pipe Spacing	15m

4.6.4 Leachate Collection Pipe network

To further assure the transport time and for redundancy, a network of collection pipes in a chevron/herringbone pattern will be installed, with 150mm diameter laterals spaced nominally 15m center to center, and a central 300 mm diameter header pipe.

Pipes could be of polyethylene, concrete or steel. Steel and concrete pipes would need epoxy coating to ensure longevity in the landfill, which would be costly. Polyethylene (HDPE) offers the most suitable material to provide maximum chemical resistance to leachate constituents.



(ii) Herring Bone Pattern

Figure 12: Herring bone pattern of pipe layout

The collection/drainage pipe system layout over the landfill area is clearly illustrated in **appendix 3.** This is part of our fourth objective to design a leachate collection system for the landfill.

4.6.5 Leachate Sump (Retention pit)

A sump will be located at the lowest elevation of the base, serving to collect the leachate by gravity in preparation for removal. The leachate is removed from the sump by pumping it to the storage tank ready for treatment. A low volume sump has to be constructed successfully from reinforced concrete pipe on a concrete footing (typically minimum 1m diameter), and must contain a valve which controls the discharge of leachate from the landfill. The collection sump (leachate retention pit) shall be located outside the landfill area as shown in the figure below.

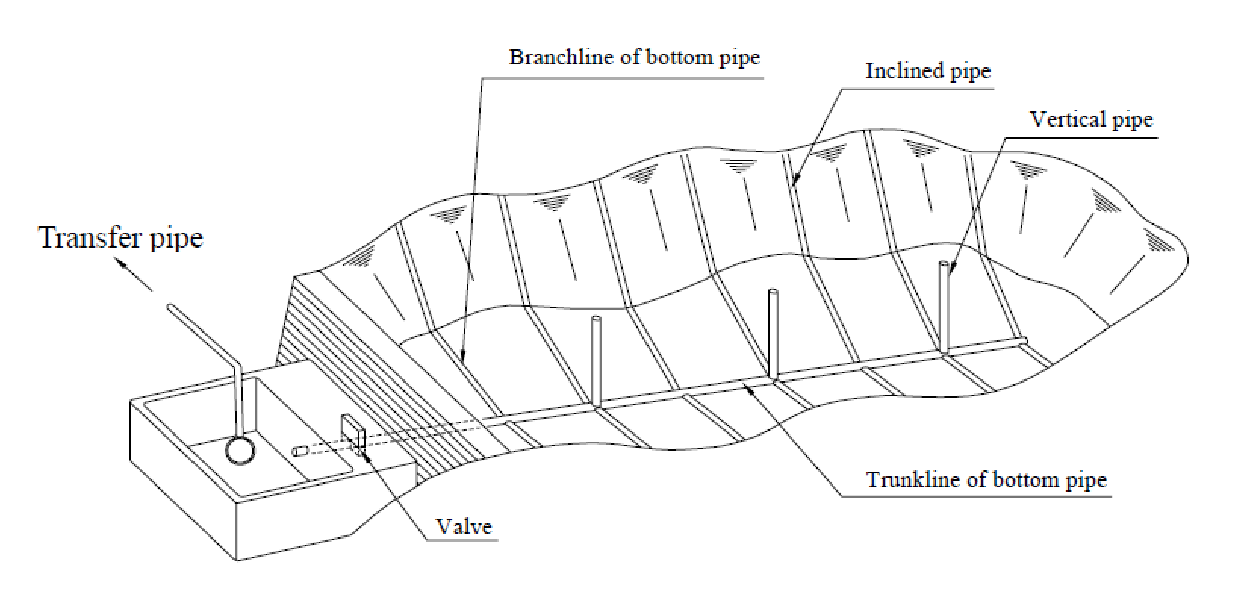


Figure 13: Retention pit outside the landfill area

4.6.6 Removal and Storage of the Leachate

a. Removal of leachate from a landfill will be carried out in either of two manners: by installing a pipe through the side of the fill or by placing a sloped collection pipe inside the fill.
b. If a pipe is placed through the side of the landfill, the construction should be conducted with due caution in order to avoid damaging the liner system.
c. Manholes and vertical and /or horizontal cleanouts will be provided in strategic locations in order to conduct periodic maintenance and inspection.
d. Once the leachate is captured, it's usually stored in tanks. The type and size of the storage device will depend upon the quantity and characteristics of the leachate, proximity to inhabited areas, and the type of treatment required.

4.6.7 Leachate treatment and disposal

The leachate collected and stored in the tank may be directed to a Leachate treatment plant or disposal to a waste water treatment plant for treatment before final disposal into a water, river or sewer.

For the case of this project, the leachate shall be directed to a waste water treatment plant since it is highly economical provided that the landfill is just near the plant. This was considered after analyzing the cost of constructing a leachate treatment plant, and also its operating costs, considering the local government's aim of minimizing the costs of managing solid wastes.

This concludes the fourth objective of providing a leachate treatment plant where the leachate can be treated before disposing it to land or water body.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

According to the research made, solid waste generation i.e. daily generation rate per person was 0.65kg/day.

The management of Municipal Solid Wastes (MSW) in Kapchorwa Municipality still has many problems. The current regulation system is not perfect and the existing management system and the collection facilities do not fit the present requirements. Municipal solid wastes are still collected without separation at the source, treatment facilities are limited and the collected wastes are mostly dumped haphazardly in open areas. The study was able to come up with suitable waste management options that would help with the problem of waste management in the area. Among others, the major ones include the following; reducing the rate of waste production, or reduce the amount generated, reduction in the negative impacts of the waste that is generated by proper waste disposal, recovery of wastes in different forms i.e. the materials recovered from the waste stream for recycling into new products, recovering materials for reuse, recovering energy by incineration, anaerobic digestion, or similar processes, reducing the volume of waste prior to disposal and disposal of residual solid waste in an environmentally sound manner, specifically in landfills.

The study was able to come up with a conceptual design of landfill to handle the biodegradable wastes (wastes that cannot be reused or recycled), with a very clear view that with its implementation, it would help curb the problem of open dumping with its associated environmental and health impacts.

5.2 RECOMMENDATION

For the recovery practice to be practicable, the government should provide market for the materials recovered from the solid wastes in order to inspire the local people to recover materials like plastics, metals, ceramics, and glass. This can be reused directly the way they are, or recycled into other valuable products.

For the wastes calculated, population was assumed to be the only factor which influences the waste generation rate. This doesn't consider the impact of other factors like the peoples lifestyle, income levels, and urbanization; yet these factors have a significant impact upon the population growth rate and waste generation rates. Other measures should be employed to consider these impacts for accurate data.

Weighing of solid waste or percentage composition studies have not been done except for weight estimates through use of capacity of garbage collecting tractor. This data can't be dependable and therefore the national statistics were considered in this project. Onsite data collection and analysis about the solid waste generation rates and composition should be done in order to acquire accurate data about the study area.

The government should setup appropriate pollution discharge standards for solid waste disposal facilities such as effluent and emission standards either based on World Health Organization (WHO) norms or related to the national standards for pollution control.

There should be provisions for subsidies (grant, soft loan, etc.) from government to municipal council including the private sector, NGOs and CBOs; in order to enable them manage solid wastes appropriately for the good of both the population and the environment.

The appointment of responsible governmental agencies that can regulate and supervise MSWM activities of both municipal council and private operators should be encouraged so as to reduce the environmental impacts of improper solid waste handling and disposal.

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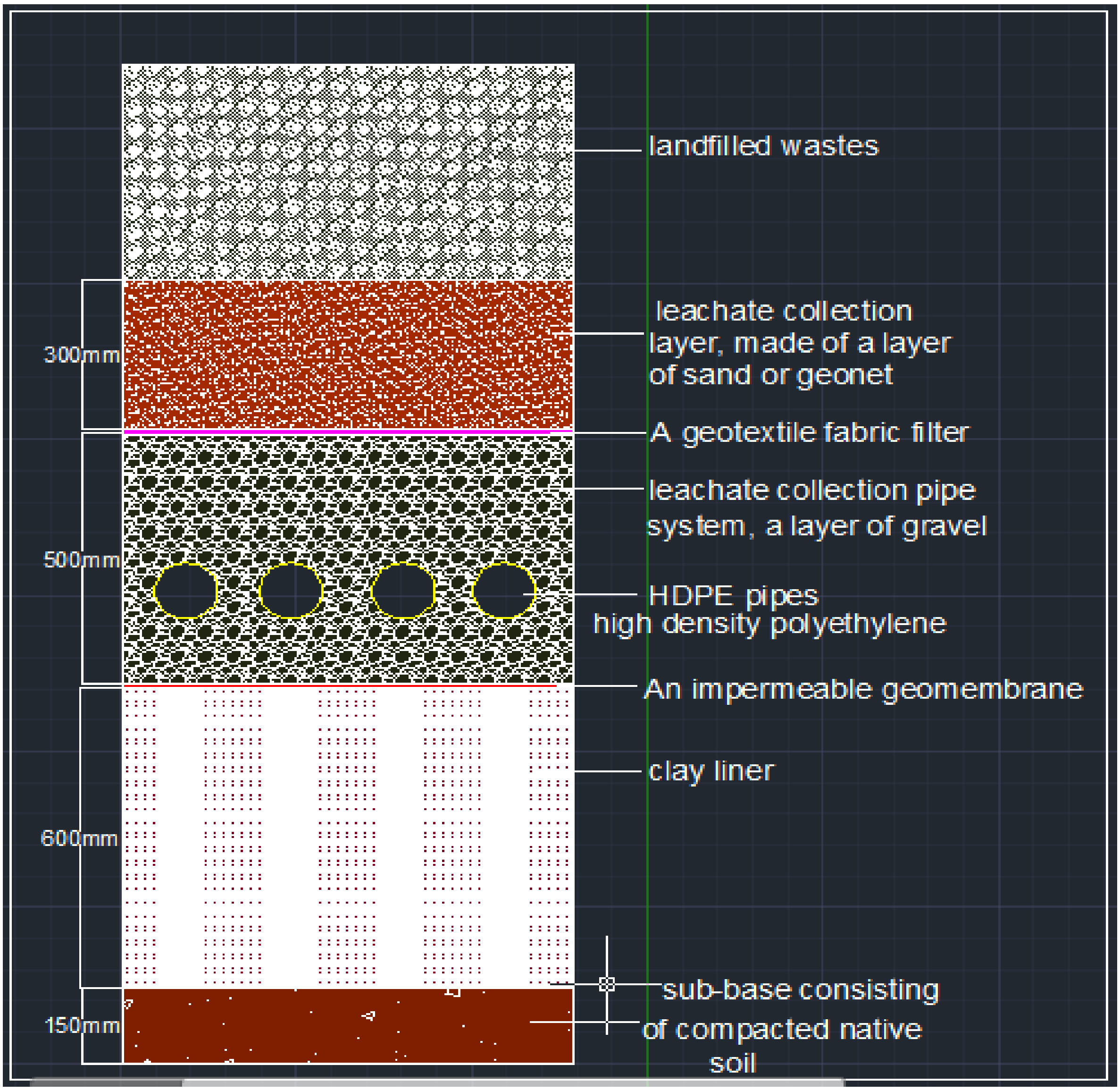
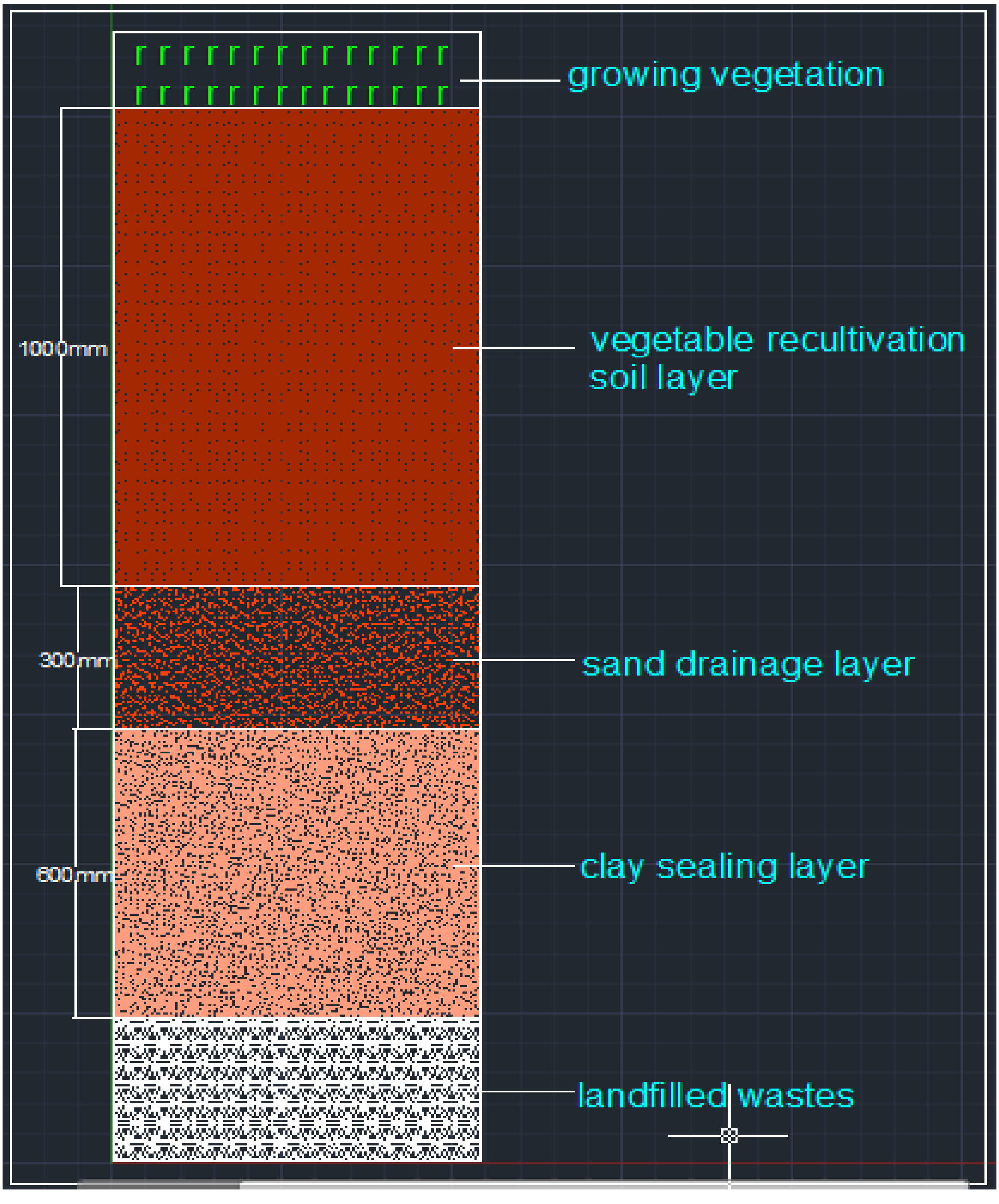
APPENDICES

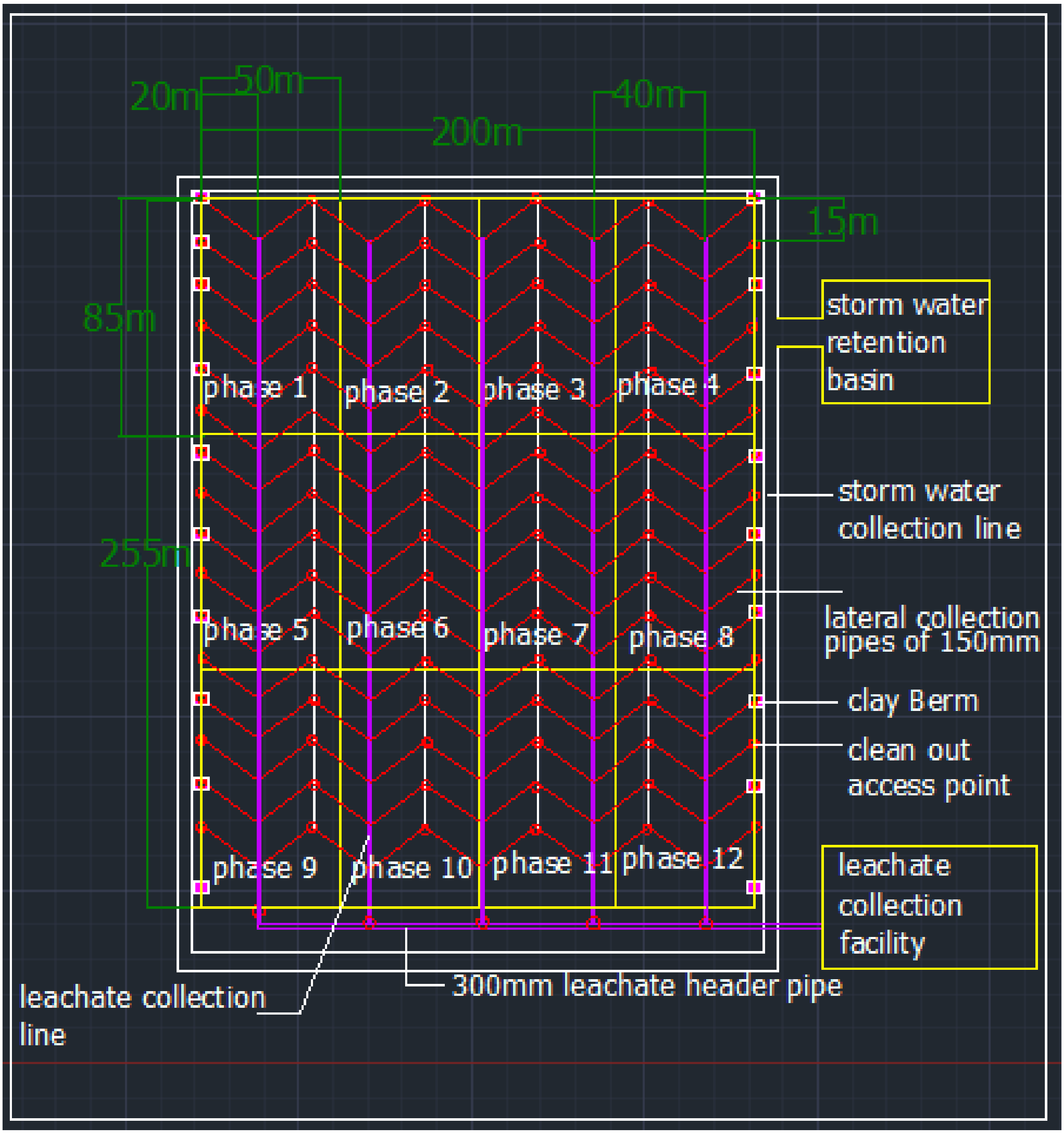
Appendix 1: Landfill liner layers below the compacted wastes



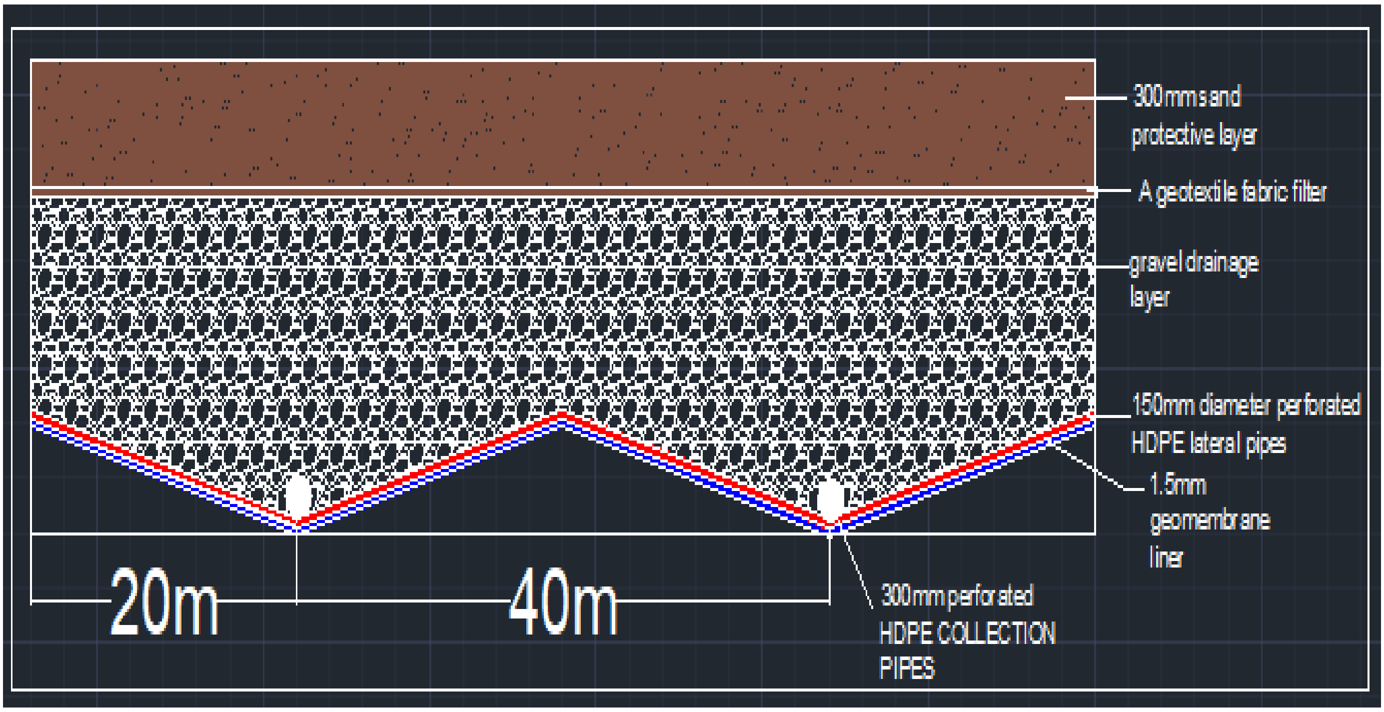
Appendix 2: landfill liner layers above the compacted solid wastes



Appendix 3: leachate collection pipe system layer out



Appendix 4: Leachate collection layer cross section



Appendix 5: Budget

S/n	ITEM	COST
1	stationary	100,000
2	Drawings	300,000
3	Data collection	250,000
4	Transport	200,000
5	Lunch	150,000
6	Miscellaneous	150,000
TOTOAL		**1,150,000**