



**A MINI SANITARY LANDFILL DESIGN AND OPERATION FOR THE ANANTIGHA COMMUNITY, SOUTHERN - NIGERIA: AN EXTENUATION METHOD TO RESOLVING MUNICIPAL WASTES THREATS.**

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**Abstract**

The Anantigha Community is located at 540252 in Calabar South. It has a current population of slightly above 88,000 residing in a land area of not less than 5,000ha, but with no feasible municipal waste management/recycling facility clearly in place. The Community's municipal waste generation per capita per day is roughly 1.67kg, implying that not less than 53,640,400kg of waste is generated annually. This makes practicable and satisfactory wastes disposal, oftentimes, a problem. This study was first aimed at evaluating the preliminary requirements for the possible design, construction, and management of a workable sanitary landfill for the community, as well as the contiguous land areas based on existing literature and operational guidelines for littoral regions like Calabar where the community is domiciled. Based on the review study, a 10m x 10m x 3m sanitary landfill was proposed for design, construction, and management as a pilot project/model for a start for the community. The next step was aimed at assessing the need for a sanitary landfill operation in the community and to evaluate the possible environmental impact of a sanitary landfill when properly operated and its effectiveness in waste disposal. The specific objectives included the determination of the amount of solid wastes generated in the community, reduction in the amount of wastes to be disposed off by determining the amount of recoverable materials, (re-use and recycle). The pilot model was subjected to series of tests before and after operation in order to examine the effectiveness or otherwise of the landfill. In view of the above, series of laboratory tests were carried out on the soil samples before and after operation to determine the various level/amount of such physico-chemical parameters like Nitrates (NO<sup>-3</sup>), Total Hydrocarbon (THC), Sodium (Na<sup>+</sup>), Potassium (K<sup>2+</sup>), Dissolved Oxygen (DO), Temperature (°c), Total Dissolved Solid (TDS), Potential of Hydrogen (pH), Electrical Conductivity (EC), present in the soil and to determine the possible effect the landfill might have on its environment after operations as well as comparing its values with the

standard permissible values for Nigeria. It was observed that the Potential of Hydrogen (pH) before operation has a value of 7.09 and that after operation has a value of 7.15 which indicates that the pH before operation and after operation are neither alkaline or acidic in nature but neutral since its values fell within the neutral range (6.5-7.5). It was also discovered that Nitrite, Total Hydrocarbon, Sodium, Potassium, Dissolved Oxygen, Temperature, Total Dissolved Solid, Electrical Conductivity all fell within the permissible values according to the Nigeria Standard for Drinking water Quality (NSDWQ) (2017) and WHO (2017), which implied that the surrounding environment was not affected by the landfill. Hence the Landfill was deemed safe and friendly to its environment. It has been recommended that in order for the recovery practice to be easily practicable and competitive, the community should provide market for the materials recovered such as plastics, metals, ceramics, and glass from the solid wastes in order to inspire the local people or residents who might employ this approach as an alternative financial gateway. The recovered materials could be reused directly the way they are, or recycled into other valuable products. The community should give management of wastes the seriousness it demands because it can serve as a source of wealth while, at the same time, adds to the aesthetics of the community by helping maintain a sustainable environment for the Anantigha community.

**Key Words:** Design, construction, management, sanitary landfill, Anantigha community, contiguous



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## **1.0 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 countries 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 vermin compost, biogas, and biochar, 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 production of garbage will always occur as long as there is life on the planet earth and human activities take place on a daily basis. The entire process of extracting advantages from raw materials while producing leftover complexity is encompassed by human activity. This complex nature has been linked to civilization, higher living conditions, and man's economic and cultural characteristics in his surroundings.

Nigeria, the most populous rising nation in Africa with a population of over 150 million, should not be disregarded when considering the environmental effects of its waste generation, disposal and management policies. With a projected yearly rate of around 0.5 to 0.7% and existing statistics ranging from 0.4 to 0.8 tons/capita/annum, national trash generation is growing at an alarming rate. Wastes is becoming more complicated, with biodegradable waste making up more than half of all wastes. This translates to an annual garbage burden of roughly 50 million tons in a country with a waste treatment capacity of less than 10%. (Akinjare et al, 2011).

The amount of waste produced per person is anticipated to increase at a rate of 1% to 1.3% annually based on existing patterns. Sustainable development, as defined by the International Commission on Environment and Development in 1987, is a development that satisfies current needs without endangering the capacity of future generations

to meet their own needs. (Environment Agency, 2014). A landfill is defined as the planned placement of waste onto and into a land so as to prevent environmental contamination or harm and to create land that can be used for other purposes through restoration. A sustainable landfill is typically built and run in a manner that minimizes both immediate and long-term environmental risks. (Environment Agency, 2014). Over the last ten years, experimental testing and field pilot studies have been done to create and improve landfill processes and designs to promote solid waste degradation, such as reducing leachate treatment time, enhancing methane production, and accelerating waste sinking, as a result, air space recovery and contamination life span reduction are possible. Leachate recirculation and the addition of nutrients and sludge are two techniques used to improve the degradation process (Environment Agency, 2014). Leachate recirculation in landfill bioreactors is gaining popularity as an efficient approach to improving municipal solid waste's microbial breakdown (Environment Agency, 2014).

For most developing-country cities, the most cost-effective solid waste disposal method is a sanitary landfill. Composting solid waste is 2-3 times more expensive than sanitary landfilling, while incineration is 5-10 times more expensive. A sanitary landfill is a built and self-contained bioreactor and attenuation structure that facilitates anaerobic biodegradation and consolidation of compacted garbage materials within confining layers of compacted soil. At a landfill, there are no annoyances such as regular burning,

smoke, flies, windblown litter, or unsightly garbage mounds proper sanitary landfill.

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 byproducts (Acosta et al., 2012). 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 adequately managed (Acosta et al., 2012). Sanitary landfills in arid areas, where leachate generation is negligible, may have less stringent construction standards than those in wet ones. Similarly, sanitary landfills on coastal lands that are underlain by naturally saline and unpotable groundwater may have less stringent construction standards than those in inland areas that are overlain by possibly useable groundwater regimes (Acosta et al., 2012). Impermeable landfill lining may be unneeded in these places with low effect potential. Instead, 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 vermicompost, biogas, and biochar, but only with efficient waste separation processes (Acosta, et al., 2012). In Europe, America, and other industrialized countries, the notion of waste separation at the 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 (Acosta et al., 2012).

Waste separation, in practice, is the categorization of garbage to ensure that each waste generated is classified. Sorting through wastes to decide what can be recycled, what should be disposed off in a landfill, and what requires special management, such as hazardous waste, is part of this process. To work, waste separation requires everyone's cooperation. Typically, three containers are placed at a collection site, one for each sort of wastes. One can be for organic garbage, one for non-recyclables, and one for other recyclable and biodegradable items. The bins would be color-coded to ensure that landfill sites were placed in the appropriate receptacle (Acosta et al., 2012).

Waste separation is the best solution to waste management concerns and also to extend the life of landfill sites. Trash separation necessitates the use of land for composting biodegradable waste, and proper waste management can be addressed by the 3R policy (Masocha, 2014). The 3R strategy, which focuses on reducing trash, reusing waste, and recycling waste, leads to the separation of biodegradable and non-biodegradable waste and is depicted in Figure 1 as a schematic of the development plans (Masocha, 2014). This method is also feasible provided sanitary landfills are correctly built and operational.

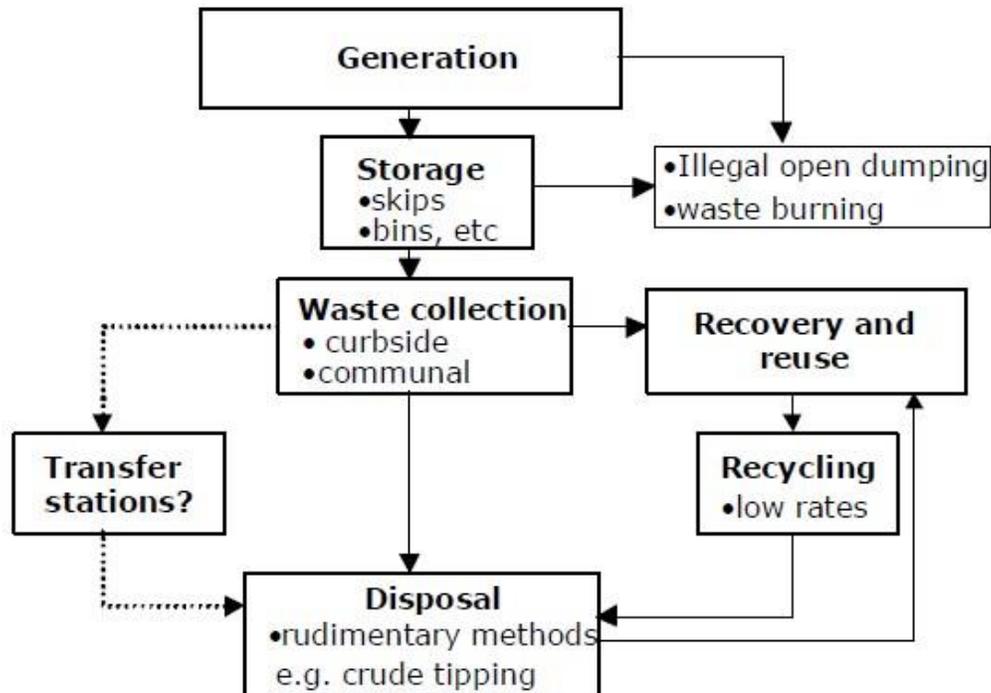


Figure 1: Possible solid waste management routes in developing countries (Adapted from Masocha, 2014)

In all parts of the Anantigha community, there are poor final solid waste disposal methods like open dumping which is a major problem in the community due to lack of a proper final disposal facility like a landfill. This open dumping of wastes has degraded the environment through the major categories of pollution to the environment such as; air, soil and water pollution, and also cause serious health problems to the population community as it

harbors mosquitoes which cause malaria.

Poor final solid waste disposal has become a serious problem in the “Anantigha” community and its environ. This is evident by the presence of open dump disposal of wastes which has led to several health problems to the residents in the community and also degrade the value of the community. The poor

solid waste management creates favorable conditions that harbor bacteria’s which transmit dangerous diseases for example mosquitoes, leads to water pollution, bad odors, blockage of water channels, detreat the authenticity of the environment.

The objectives of the study included the following:

- i. To assess the need, or otherwise for a sanitary landfill operation for the Anantigha community;
- ii. To examine the quantity of solid wastes generated in the community.
- iii. To explore ways to minimize the quantity of wastes to be landfilled by determining the amount of recoverable material, (re-use and recycle).

- iv. To design, construct and manage a sanitary landfill in the Anatigha community.

**2.0: Design of Sanitary Landfill**

A proper and detailed design of a sanitary landfill cannot be archived without considering the following as a major key:

- i. Location of a suitable site
- ii. Determination of the lifespan/target year
- iii. Carrying out financial analysis and determining the construction schedule of the landfill.

- iv. Designation of the service area, analysis of waste haulage, and the projected quantity must also be taken into account while designing a sanitary landfill.

Excessive buildup of waste in sanitary landfill design can easily be avoided by providing some buffer or reserve margin in the plan so that the life span of the landfill may be increased by a further 10 years period for allowance for a transition period.

Unlike the usual technique, this design approach will determine the amount of land needed based on the rate of waste creation and

the necessary number of compartments to be chosen based on the landfill's expected life. The following variables were taken into account.

- i. Waste in landfill density, kg/m<sup>3</sup>
- ii. Daily total garbage production (tons)
- iii. Annual trash production (tons)
- iv. Compostable solid waste fraction, followed by non- organic/reusable solid waste fraction.
- v. Effective collection
- vi. The portion that will be landfilled
- vii. Landfilling effectiveness
- viii. Landfill base length (Yedla, 2005).

**2.1: Fundamental Design Conditions**

The fundamental elements of design were as follows: A three-year maturation phase was considered for the landfill

**2.1.1 Designed Capacity of the Landfill**

The amount of garbage that is anticipated to be dumped (ADLV) and the amount of soil (CMV) that will be covered each year are multiplied by the number of years the landfill will be in operation to arrive at the designed landfill capacity (DLC).

$$DLC [m^3] = \text{goal lifetime [year]} \times (\text{ADLV [m}^3 \text{/year]} + \text{CMV [m}^3 \text{/year]}) \dots\dots\dots \text{(Eqn.1)}$$

By dividing the annual designed landfill weight (ADLW) by the specific weight (SWW) (or weight per unit volume) of the solid waste that is landfilled and compacted, yielded the annual designed landfill volume (ADLV).

$$SWW [\text{ton/m}^3] = \text{ADLW [\text{ton/year}]} / \text{ADLV [m}^3 \text{/year]} \dots\dots\dots \text{(Eqn.2)}$$

The annual designed cover material weight (ADCMW) is divided by the specific weight (SWCM) (or weight per volume) of the compacted and landfilled cover material to get the cover material volume (CMV).

$$SWCM [\text{ton}/\text{m}^3] = \text{ADCMW} [\text{ton}/\text{year}] / \text{CMV} [\text{m}^3 / \text{year}] \dots\dots\dots (\text{Eqn.3})$$

After determining DLC, the site that can guarantee the capacity needed to fill DLC is often chosen. The condition of a secure site determines the amount of space needed for a dump site. Target lifespan will alter in accordance with DLC

**Assumptions**

The generating rate per capital will rise by 2% /year.  
Population growth equals 4% a year.

**Table 1: Waste Generation Composition**

S/N	Material	Quantities Q(Kg/Day)	Percentage (%)
1	<b>Organic wastes</b>	27,908.84	49.775
2	<b>Paper</b>	7,169.95	12.7875
3	<b>Plastic</b>	4,709.88	8.4
4	<b>Glass</b>	2,102.63	3.75
5	<b>Metal</b>	3,069.83	5.475
6	<b>Textile &amp; leather</b>	2,684.35	4.7875
7	<b>Inert &amp; others</b>	8,424.52	15.025
		<b>56,070.00</b>	100

Taken a generation rate of 1.67kg/capita/day, it was discovered that a total of 56,070.00kg/capital/day was generated.

**2.1.2: Amount of Waste Recovered**

Material recovery technics was employed in other to reduce the amount of landfilled materials to be used. Plastics, metals, paper, glass, textile, leather, inert and other wastes were recovered through sorting and could be re-used and, or recycled. This amounted to a 50.225% percentage (28,161.1575/day) of the total waste gotten while 49.775% percentage (27,908.8425/day) was left to be landfilled.

**2.1.3: Landfill Size (Volume and Area)**

The design landfill capacity was used to determine the area required for the construction of the landfill. 3 years designed life was adopted for this research.

**2.2: Projection Population for The Anantigha Community, Calabar South**

The population of the community as at 2021 was 67,000 people,

a population growth rate of 9.6% percentage, annually was adopted.

The year-by-year population projections for the community was then computed using the following equation

$$P_F = P_P \times R \dots\dots\dots(\text{Eqn.4})$$

Where  $P_F$ = Future Population

$R$  = rate of increment

i.e. population for  $P_{2022} = P_{2021} \times R = 67,000 \times 9.6\% = 6,432$  People

$$P_{2023} = P_{2022} \times R = 73,432 \times 9.6\% = 7,049 \text{ people}$$

$$P_{2024} = P_{2023} \times R = 80,481 \times 9.6\% = 7,726 \text{ people}$$

Therefore, the design population was  $P_{2024} = 88,207$  people

**2.2.1: Waste Generation Projection for The Design Population**

The projected population was used to obtain the quantity of wastes for the design life of the landfill. The following formula was used to carry out the estimate.

$$WG = P_N \times R \times 365 \times DL \dots\dots\dots(\text{Eqn.5})$$

Where D.L is the design life of the landfill

$P_N$  is the design population

$R$  is the waste generation rate

$$WG = 88,207 * 0.67 * 365 * 3 = 64,713,065.6 \text{ kg produced by 2024}$$

From table 1. above, 50% of these wastes is to be landfilled, therefore the amount of wastes to be landfilled by the design life of the landfill is got from;

$$\text{Wastes to be landfilled } WL = (50/100) * 64,713,065.6 = 32,356,532.8 \text{ kg.}$$

d. Amount of wastes landfilled by the design year  $WL = 32,356,532.8$  kg

e. Apparent waste density =  $500 \text{ kg/m}^3$  or  $0.5 \text{ tonnes/m}^3$

h. Minimum of 0.2meter thickness of vegetable final cover.

k. Adopt a height of fill to be 3m

**2.2.3: Volume of Wastes, Volume of Daily Cover, and the Volume Required For the Components of Cover and Liner System.**

i The Volume of Wastes:

$$VM \text{ was obtained from } VM = WL / AWD = 32,356,532.8 \text{ kg} / 500 \text{ kg/m}^3$$

$$VM = 64,713.1 \text{ m}^3$$

**2.2.2: Considerations of The Landfill Design**

a. Design population of 2024 = 88,207 people

b. Total quantity of wastes generated  $WG = 64,713,065.6$  kg by 2024

c. Waste generation rate =  $0.67 \text{ kg/capita/day}$

- ii Total volume of daily cover (VDC) was assumed as 1% of the volume of waste to be
- $$VDC = (1/100) * 32,356,532.8 = 323,565.3 \text{ m}^3$$

landfilled.

#### 2.2.4: Required Volume for Components of Cover and Liner Layers

The leachate collection layer was computed from

$$V_c = k V_m \dots \dots \dots \text{(Eqn.6)}$$

Where K was taken as 0.25 for landfills with height up to 10m (Technical Guideline for sanitary landfill design and operation ,2004). 1.0m and 1.5m respectively were adopted as cover and liner layer, including leachate collection.

$$V_c = 0.25 \times 64,713.1 = 16,178.3 \text{ m}^3$$

#### 2.2.5: Landfill Capacity or The Volume of Landfill

$$LC = V_m + V_{dc} + V_c \dots \dots \dots \text{(Eqn. 7)}$$

$$= 64,713.1 \text{ m}^3 + 323,565.3 \text{ m}^3 + 16,178.3 \text{ m}^3$$

$$CL = 404,456.7 \text{ m}^3$$

#### 2.2.6: Required Area for The Landfill and Other Facilities

- iii The required area for the landfill AL, was obtained from = volume of landfill / height of fill

Adopting a height of the landfill as 3m, AL =  $404,456.7 \text{ m}^3 / 3$

$$AL = 134,818.9 \text{ m}^2$$

- iv for additional area A2, required for roads networks, control building, border setback areas and sanitary facilities, etc. has been taken as 20% of the area to be landfilled for the design life.

$$A2 = (20/100) * 134,818.9$$

$$A2 = 26,963.8 \text{ m}^2$$

Therefore, the total area required for the landfill and its associated facilities was given by;  $A = A1 + A2 = 134,818.9 + 26,963.8$

$$A = 161,782.7 \text{ m}^2$$

#### 2.3: The Design of The Landfill Liner

A composite liner system was considered due to its effectiveness to limit leachate migration with a geo-membrane in conjunction with a clay liner. In other to achieve low permeability for landfill bottom layer, clay material was compacted at the bottom with hydraulic conductivity less than or equal to  $1 \times 10^{-7} \text{ m/s}$ . This was obtained by using a 600mm thick layer of clay, compacted to 150 mm layers. A low-permeability clay material was compacted to achieve a specified minimum permeability base and sidewall mineral layer with hydraulic conductivity less than or equal to  $1 \times 10^{-7} \text{ m/s}$ .

#### 2.4: Design of The Final Cover

A landfill cover was constructed to:

- prevent waste disturbance to the environments in terms of pollution;
- support vegetation for landfill rehabilitation thereby using good uncompacted natural soil to prevent

- erosion and allowing the dump to be blended into the surrounding region as part of the site restoration/reclamation;
- the overall final cover thickness of 0.8m of uncompacted natural soil helped to reduce waste disturbance in the long run, and allowing a minimum of 150 mm-controlled infiltration of precipitation.

### 3.0: Results and Discussions

Series of laboratory tests were carried out on the soil samples before and after operation to determine soil parameters such as Nitrates ( $\text{NO}^{-3}$ ), Total Hydrocarbon (THC), Sodium (Na), Potassium (K), Dissolved Oxygen (DO), Temperature, Total Dissolved Solid (TDS), Potential of Hydrogen (pH), Electrical Conductivity present in the soil and to determine the possible effect the landfill might have on its environment after

operations as well as comparing its values with the standard permissible values for Nigeria Standard for Drinking Water Quality (NSDWQ) and the World Health Organization (WHO) standards. It was observed that the Potential of Hydrogen (pH) before operation had a value of 7.09 and that after operation, a value of 7.15 which indicated that the pH before operation and after operation fell within the neutral range (6.5-7.5). Nitrite, Total Hydrocarbon, Sodium, Potassium, Dissolved Oxygen, Temperature, Total Dissolved Solid, Electrical Conductivity all fell within the permissible values according to the Nigeria Standard for Drinking water Quality (NSDWQ) (2017), WHO (2017). This showed that the surrounding environment was not affected by the landfill operation. Hence the Landfill was certified safe and friendly to its environment.



Figure 2. 10m×10m×3m Excavated landfill trench for the pilot Model



Figure 3: Section showing the placement of liner material and pipes for monitoring above the compacted subgrades



Figure 4: Waste placed in different layers of the landfill

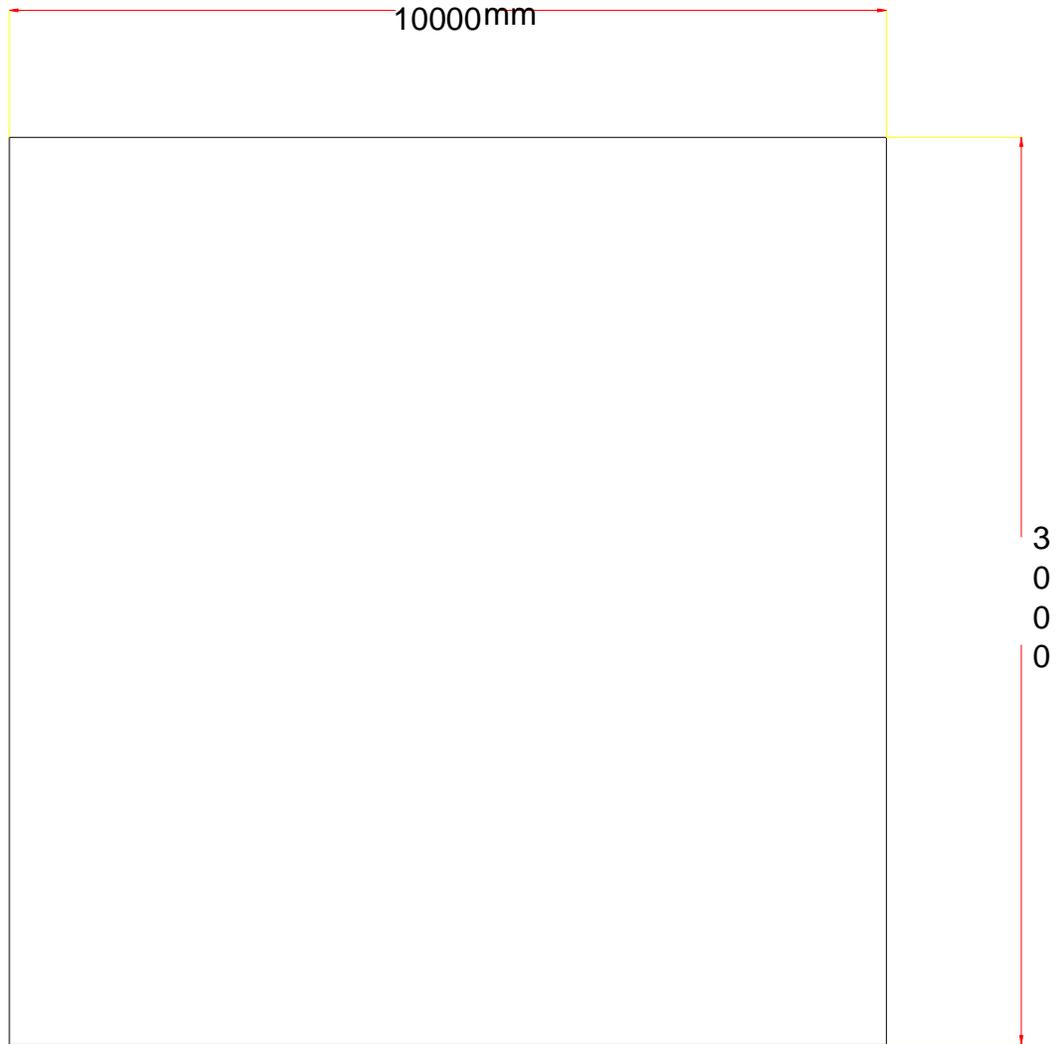


Figure 5: Plan View of a 10m\*10m\*3m Mini Sanitary Landfill for The Anantigha Community

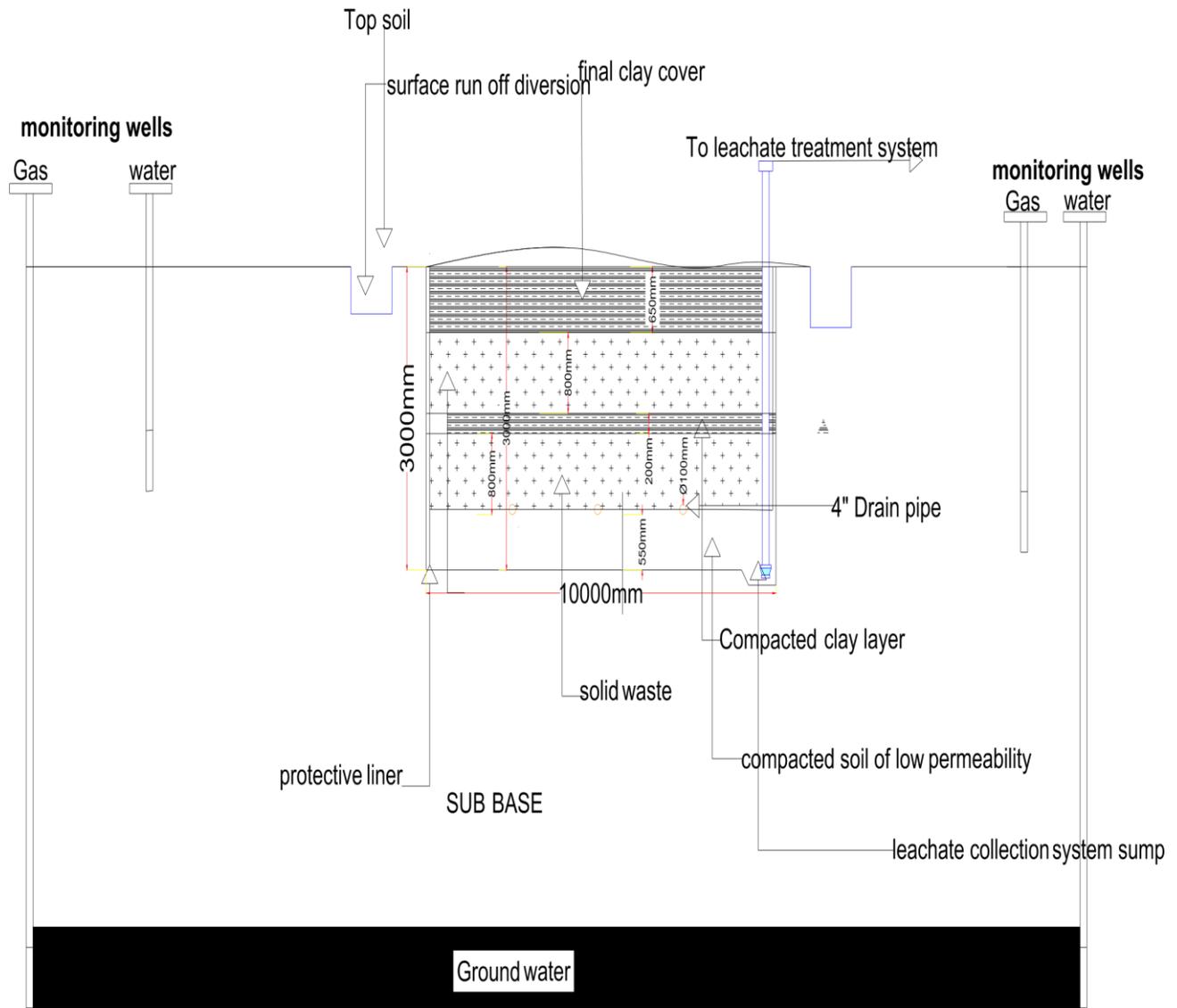


Figure 6. Cross Sectional View of a The Constructed Mini Sanitary Landfill for The Anantigha Community, Calabar.

#### 4.0: Conclusion and Recommendation

##### 4.1 Conclusion

From this work, it was observed that a solid waste generation rate for the Community stands at 1.67kg/capita/day. From the above, a mini sanitary landfill of 10m×10m×3m prototype was constructed as a pilot model for the community.

It was observed that the solid wastes are still being collected without separation at the

source. Facilities are limited and the collected wastes are mostly dumped haphazardly in open areas which tend to cause harm to the environment. The study was able to come up with suitable waste management options that would help with the problem of waste management in the Anantigha community. Among others, the major ones include the following;

- i Reduction in the rate of waste production which should essentially reduce the amount of waste generated daily.
- ii Reduction in the negative impacts of the wastes that are generated through proper waste disposal approach, e.g. sanitary landfill.
- iii Recovery of wastes in different forms i.e. the materials recovered from the waste streams which are recyclable.
- iv Recovery of materials for reuse and reducing the volume of waste prior to disposal and disposal of residual solid waste in an environmentally friendly manner, specifically in landfill.

In this research material recovery technics was employed in other to reduce the amount of landfilled materials to be used. Plastics, metals, paper, glass, textile, leather, inert and other wastes which could be re-used and recycled, were recovered through sorting. This amounted to 50.225% percentage (26,820.15kg/day) of the total waste gotten while 49.775% percentage (26,579.85kg/day) was left to be landfilled.

#### 4.2 Recommendations

Based on the results and discussions, it was recommended that in order for the recovery practice to be easily practicable and competitive, the community should provide a ready market for the materials recovered such as plastics, metals, ceramics, and glass from the solid wastes in order to inspire the locals. The recovered materials could be reused directly the way they are, or recycled into other valuable products.

In view of the above recommendation, the community should take the management of waste serious because it can serve as a source of wealth and also at the same time keep a sustainable environment for the community.

A standard sanitary landfill system should be built in strategic places across the community so that recycling, reuse and recovering of materials would be encouraged.

When designing a sanitary landfill, geotechnical investigations should be properly incorporated. Since decomposable waste are highly generated and decompose easily, sanitary landfill should be designed base on all types of decomposable waste.

The management of the community 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.

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

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