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# Design of Appropriate Waste Management in Abuja Satellite Towns

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## Info Artikel

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*Solid waste management; Waste composition; Manual sanitary landfill; Abuja Satellite towns*

## Abstrak

*Sampah padat dan pengelolaannya menjadi perhatian utama Abuja dan Kota Satelitnya. Pengelolaan limbah padat yang tidak tepat telah menjadi jalan utama penularan penyakit secara global. Studi ini mengkaji penilaian sistem pengelolaan sampah di kota-kota satelit Abuja dalam berbagai kelompok sosial ekonomi, dan merancang solusi yang tepat untuk pengelolaannya. Total 257 kuesioner diberikan kepada penduduk di 50 rumah tangga terpilih di semua kelompok sosial ekonomi. Data dianalisis dengan menggunakan Statistical Package for Social Science (SPSS) 2020 dan Microsoft Excel 2010. Sebanyak 350 sampel rumah tangga dikumpulkan dengan menggunakan random sampling untuk mengetahui jumlah sampah yang dihasilkan selama satu minggu pada bulan Juni 2021. Kuantitas yang dihasilkan adalah 1091,1kg dengan laju pembangkitan 0,623kg/kapita/hari. Kajian ini merekomendasikan antara lain perbaikan pada sistem pengelolaan sampah saat ini, dan desain TPA manual sebagai solusi pembuangan.*

## Abstract

Solid waste and its management have been of major concern to Abuja and its Satellite Towns. Improper management of solid waste has been a major avenue for disease transmission globally. This study examines the assessment of solid waste management systems in Abuja satellite towns within different socio-economic groups, and design of appropriate solutions for its management. In total 257 questionnaires were administered to residents in the 50 selected households across all the socio-economic groups. The data was analyzed using Statistical Package for Social Science (SPSS) 2020 and Microsoft Excel 2010. A total of 350 samples were collected from the households using random sampling to determine the amount of solid waste generated during one week in June 2021. The quantity generated was 1091.1kg with generation rates of 0.623kg/capita/day. The study recommended amongst others improvement on the present system of managing solid waste, and design of manual sanitary landfill as disposal solutions.

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## INTRODUCTION

Environmental pollution has continued to be a source of challenge, especially through inappropriate solid waste management in many parts of the world. With the population on the increase and waste generation on the rise, effective waste management response to combat the challenges of sustainable development is a necessity if there is any chance of meeting current needs without jeopardizing the potentials and ability of future generations to meet theirs [1]. As the quantities of Solid waste produced in cities continue to increase daily, the effectiveness of waste management systems in terms of collection, transportation and disposal remains undesirably low in most parts of developing countries [2].

Wastes are substances which is disposed of or intended to be disposed of or needs to be disposed of [3]. Similarly, it can be defined as any material that is no longer needed or no longer useful to the owner. Wastes can be solid, liquid or gaseous materials. However, the focus of this research will be solid wastes.

Solid wastes are defined as all the wastes arising from human and animal activities that are normally of solid nature and are discarded as useless or unwanted by the person or organization that produces the wastes. Solid wastes are often called Municipal Solid Wastes (MSW), and it consists of all the solid and semisolid materials.

Solid waste can mean different things to different people [4]. Some people (waste pickers) believe that waste is a source of revenue and income. While others see waste as a problem that must be addressed and solved.

Therefore, solid wastes management (SWM) includes the activities and actions required to manage waste from its source of generation to its final disposal. This includes the collection, transport, treatment and disposal of together with monitoring and its management process waste-related laws, technologies, economic mechanisms amongst others.

The volume of waste generated in Abuja satellite towns has grown steadily as a result of the increasing population, changing life-styles, and increasing use of disposal materials. The challenges posed by this waste are that it is generated at a pace much faster than the availability of its management facilities. Solid wastes from these Towns are not safely and reliably managed accurately and effectively. The existence of insufficient capacity makes impossible the management of solid waste.

The aim of this study is to investigate the solid waste management systems in Abuja satellite towns and design appropriate solutions to its management.

The areas covered in Abuja Satellite Towns include Nyanya, Orozo, Karu, and Karshi wards and have large concentration of inhabitants. This study focused mainly on the quantity and composition of household waste, assessment of solid waste management systems using the waste generated in different socio-economic groups, and design of appropriate waste management as disposal solution.

According to Keseret al, 2012 [5] consumption patterns are affected by many factors relevant to socioeconomic, environmental and demographic conditions and affects the type and quantity of waste generated. Ogbonna et al., 2002 [6] opined that domestic waste production in Nigeria is on the increase and is compounded by a cycle of poverty, population explosion, decreasing standards of living, bad governance, and low level of environmental awareness. Consequently, in Nigeria indiscriminate disposal and dumping of solid waste is a common practice around most residential areas.

This research contributes towards developing a better understanding of the waste management challenges being faced in some communities in satellite towns with recommendations for improvement, and our knowledge on disposal solution in satellite towns where there is little/no existing research. With the projected increases in waste and urban population growth, this makes the research very important and timely.

### Study Area

Abuja Municipality, the study area is the capital of Nigeria and a fast growing city created in 1976. The growth of the Federal Capital Territory (FCT) as a result of the huge influx of people led to the emergence of satellite towns such as Karu, Gwagwalada, Lugbe, Kuje and smaller settlements towards which the planned city is sprawling. The FCT consists of six different Area Councils namely; Abaji, Abuja Municipal, Bwari, Gwagwalada, Kuje and Kwali. The Abuja Municipal Area Council (AMAC) is the focus of this study. The Area Council is made up of twelve (12) wards namely: City Center, Wuse, Gwarinpa, Garki, Kabusa, Gui, Jiwa, Gwagwa, Karshi, Orozo, Karu, and Nyanya. Four satellite towns/wards namely; Karshi, Orozo, Nyanya and Karu were purposively selected from the twelve wards in the study area council because of the high population density, presence of poorly planned residential houses and proliferation of open waste dumps in the areas.

## RESEARCH METHODS

The four wards purposely selected were divided and characterized into three socio-economic groups namely High-income, Medium-income, Low-income groups. The High-income group constitutes the respondents who live in the following communities; FHA Nyanya, Jikwoyi, Karu, Karu Site. While the Middle-income groups reside in Karshi, Orozo, Kurudu, Kpegyi, Mopol Road and Nyanya-Mararaba axis road communities. The other remaining communities Gbagalape, Nyanya village, Boundary Road, Phase IV/Gaduwa/Agwan Dadi, and Road IV are in Low-income group. The Communities surveyed with the total number of sampled households in the Satellite Towns are shown in Table 1. The study was undertaken and data collected from May to September 2021.

### Determining the number of Samples

The amount of waste generated varies at different places. Because of the heterogeneity and changefulness nature of MSW, the survey sample size was determined according to the principles of statistics. In the past, Researchers such as Gomez et al [7] and Abu Qdais et al [8] used this method and adapt it respectively. The optimum sample size has been estimated by selecting 99% Confidence Interval (CI) with a 10% margin of error. This method is based on the Central Limit Theorem (CLT) and sampling theory. The Central Limit Theorem relies on sample mean and standard deviation, which will also be with an error called the standard error. This tells us how well our sample data represents the whole population. As sample means are gathered from the population, standard deviation is used to distribute the data. Sample sizes equal to or greater than 30 are often considered sufficient for the central limit theorem to hold.

The optimum sample size was determined by the following equation: $n = (\frac{z\sigma}{E})^2$

Where n is the number of sample sizes, z is the score predetermined for each confidence level (e.g z = 2.58 for 99%), $\sigma$ is the standard deviation of a population, and E is the sampling error. Using the above formula, the representative sample of a population of 309,306 was 49 households, which I was to sample. However, 50 households were sampled across the different socio-economic groups.The smallest number of samples required for a 99% confidence interval with a 10% error in the mean value was 24 households in low income, 17 households in medium income, and 9 households in high income (Table 1). The percentages of each socio-economic group are 48%, 34%, and 18% respectively.

### Sample Collection

The field survey was to sample waste from individual households. The process was initiated by visiting and informing the randomly selected 50 households of the intention in carrying out the research. Black plastic bags where the householders will put their generated waste products were provided for them and their contacts requested. The bags were labeled with specific codes referring to which socio-economic groups and the status of the household selected. The essence of labeling the bags was to ensure easy and simple sorting of the waste samples of the three socio-economic income groups. Each of the households was visited eight times. The solid waste samples collected on the first day were discarded to ensure that there is no accumulation of solid waste from the previous days. The rest of the visits from day 2 to day 8 to collect solid waste generated at each household were at regular intervals. A total of 257 questionnaires were also administered to the households sampled where data regarding their demographic information and other information regarding waste management were obtained.

### Sample Sorting and Measurement

The sample bags were retrieved and taken to the nearest local sorting centres. Thereafter on-site separation and measurement were done at the locations. The contents on the bags were emptied, spread into a clean surface and sorted into six categories composition of household waste. This includes food wastes, paper/carton, plastics, glass, metals and others (Table 4).

First, the weight of the empty container using the weighing scale was determined. Thereafter the container was filled with sorted waste while shaking the container constantly to fill the voids and the figures were recorded. The final weight of the sample was calculated after the separation process for each household and each socio-economic level, this process was also used to calculate the fraction of the type of waste present in the sample. Different fractions of the samples were weighed, and the readings were used for further analysis of solid waste.

The researcher analyzed and interpreted qualitatively and quantitatively under the nature of the data that were given by respondents. Different statistical techniques like descriptive and inferential statistics was used to compare, contrast and explain the personal and existing practices of the samples. Statistical data entry was performed using software known as Statistical Package for

Social Science (SPSS) 2020 and Microsoft Excel 2010. Statistical tables, relevant illustrations, and charts were constructed for easier interpretation and discussion.

## RESULTS AND DISCUSSION

Data on demographic and solid waste management was collected across the three socio-economic groups through field survey, questionnaires administration, and face-to-face interviews. The data was analyzed and results obtained.

***Table 1: Total Number of Sampled Households according to Socio-Economic Groups***

| *S/n* | *Wards* | *Communities* | *Low Income* | *Medium Income* | *High Income* |
|---|---|---|---|---|---|
| *1* | *Nyanya* | *Gbagalape* | *9* | *-* | *-* |
| | | *FHA Nyanya,* | *-* | *-* | *3* |
| | | *Nyanya village* | *4* | *-* | *-* |
| | | *Boundary road* | *2* | *-* | *-* |
| | | *Phase IV /Gaduwa/ AgwanDadi* | *2* | *-* | *-* |
| | | *Mopol road* | *1* | *3* | *-* |
| | | *Nyanya-Mararaba road* | *-* | *3* | *-* |
| | | *Road IV* | *3* | *-* | *-* |
| *2* | *Karu* | *Karu* | *1* | *-* | *-* |
| | | *Karu Site* | *-* | *1* | *3* |
| | | *Jikwoyi* | *-* | *1* | *3* |
| *3* | *Orozo* | *Orozo* | *1* | *1* | *-* |
| | | *Kurudu* | *-* | *3* | *-* |
| | | *Kpegyi* | *-* | *3* | *-* |
| *4* | *Karshi* | *Karshi* | *1* | *2* | *-* |
| ***Total*** | | | ***24*** | ***17*** | ***9*** |

*Source: Field Survey by the Author, 2021*

### Socio-Demographic Characteristics of Respondents

This section presents background information with a review of the demographic, economic, and social features of the respondents who are representative of the population of the selected communities in the four wards and Income level groups (Table 2).

**Table 2: Description of Sampled Households**

| **Social Demographic Variable** | **Frequency (f)** | **Percentage (%)** |
|---|---|---|
| GENDER | | |
| Male | 41 | 82 |
| Female | 9 | 18 |
| **Total** | **50** | **100** |
| HOUSEHOLD SIZE | | |
| 1 | 1 | 2 |
| 2 | 4 | 8 |

| | | |
|---|---|---|
| 3 | 8 | 16 |
| 4 | 5 | 10 |
| 5 | 11 | 22 |
| 6 | 15 | 30 |
| Above 7 | 6 | 12 |
| **Total** | **50** | **100** |
| AGE | | |
| 15 – 24 | 6 | 12 |
| 25 – 34 | 20 | 40 |
| 35 – 44 | 8 | 16 |
| 45 – 54 | 10 | 20 |
| 55 – 64 | 3 | 6 |
| Above 65 | 3 | 6 |
| **Total** | **50** | **100** |
| EDUCATION | | |
| University | 11 | 22 |
| NCE | 8 | 16 |
| Secondary | 20 | 40 |
| Primary | 4 | 8 |
| None | 4 | 8 |
| Others | 3 | 6 |
| **Total** | **50** | **100** |
| INCOME LEVEL | | |
| Low Income | 24 | 48 |
| Medium Income | 17 | 34 |
| High Income | 9 | 18 |
| **Total** | **50** | **100** |

Source: Field Survey by the Author, 2021

**Table 3: MSW Generated by Households in Each Socio-economic Group**

| Number of Households | Low Income | | Medium Income | | High Income | |
|---|---|---|---|---|---|---|
| | Number of Residents | Waste Generated (kg) | Number of Residents | Waste Generated (kg) | Number of Residents | Waste Generated (kg) |
| 1 | 5 | 18.1 | 3 | 10.5 | 5 | 23.1 |
| 2 | 6 | 20.5 | 8 | 30.7 | 6 | 28.4 |
| 3 | 5 | 17.5 | 6 | 21.0 | 3 | 15.3 |
| 4 | 3 | 12.8 | 2 | 9.7 | 6 | 29.9 |
| 5 | 4 | 15.7 | 6 | 23.0 | 4 | 18.1 |
| 6 | 5 | 19.0 | 11 | 60.4 | 5 | 22.5 |
| 7 | 1 | 5.9 | 5 | 18.5 | 6 | 29.3 |
| 8 | 6 | 21.7 | 10 | 55.9 | 3 | 14.5 |
| 9 | 5 | 18.0 | 6 | 22.5 | 12 | 63.7 |
| 10 | 3 | 12.9 | 5 | 19.1 | | |
| 11 | 6 | 20.9 | 6 | 21.7 | | |
| 12 | 2 | 9.8 | 4 | 17.7 | | |
| 13 | 6 | 20.5 | 6 | 23.0 | | |
| 14 | 5 | 19.5 | 2 | 10.8 | | |
| 15 | 3 | 13.0 | 5 | 19.2 | | |
| 16 | 6 | 21.0 | 3 | 13.5 | | |
| 17 | 4 | 16.0 | 6 | 17.0 | | |
| 18 | 6 | 21.6 | | | | |
| 19 | 2 | 10.0 | | | | |
| 20 | 10 | 57.1 | | | | |
| 21 | 3 | 12.7 | | | | |
| 22 | 4 | 16.1 | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 23<br>24<br><br>**Total** | 5<br>8<br><br>**113** | 18.7<br>33.1<br><br>**452.1** | **94** | **394.2** | **50** | **244.8** |
| **Total Number of Samples** | 168 | | 119 | | 63 | |
| **Waste generation rate (kg/capita/day** | | 0.572 | | 0.599 | | 0.699 |

Source: Field Survey by the Author, 2021

**Waste Composition Analysis**

The analysis was carried out in communities within the satellite towns to ascertain the generated solid waste quantity and composition. The waste was collected from 50 selected householders of the income groups and characterized at the nearest sorting centers. The main purpose of the study was to calculate the generated waste per capita rate of households from the three income groups within communities to ascertain the composition of relative quantities of the household waste stream and thereafter identify priority materials for waste reduction.

Table 4 below shows the waste composition by weight. The total quantity of waste generated from the 50 households that were randomly selected was 1091.1kg with 257 inhabitants residing in the sampled households in the three Income level groups; this gives an average of 0.623 kg/capita/day.

Food wastes have the highest generated wastes across all the income groups with 42.05%, 38.2%, and 26.8% for low, medium and high respectively (Table 4). Generally, it was observed that the amount of waste generated by the three income groups depended on the socio-economic status of the group. The High-income group was found to generate more waste than the low and middle income groups (Table 3).

**Table 4: Waste Composition Sampled by Weight and Percentage**

| Waste category | Low Income | | Medium Income | | High Income | |
|---|---|---|---|---|---|---|
| | Total waste (kg) | Percentage of waste (%) | Total waste (kg) | Percentage of waste (%) | Total waste (kg) | Percentage of waste (%) |
| Food | 189.7 | 42.0 | 150.5 | 38.2 | 65.7 | 26.8 |
| Paper/carton | 60.8 | 13.4 | 71.2 | 18.1 | 50.1 | 20.5 |
| Plastics | 34.8 | 7.7 | 40.3 | 10.2 | 31.0 | 12.7 |
| Glass | 30.3 | 6.7 | 39.6 | 10.0 | 32.9 | 13.4 |
| Metals | 20.9 | 4.6 | 30.7 | 7.8 | 25.1 | 10.3 |
| Others | 115.6 | 25.6 | 61.9 | 15.7 | 40.0 | 16.3 |
| **Total** | **452.1** | **100** | **394.2** | **100** | **244.8** | **100** |

Source: Field Survey by the Author, 2021

**Design of a Manual Sanitary Landfill**

Given the assessment carried out, it is recommended that the design of Manual Sanitary Landfill is appropriate for sustainable solid waste management in the study area (Figure 1). Manual Sanitary Landfill is the type of Landfill use for final disposal of municipal solid waste in small communities in which quantity and type of waste produced is less than 15 tons/day, and their insecure or unstable economic situation cannot afford them to buy heavy machines because of its high costs of operation and maintenance. The manual operation requires heavy equipment only to dig the trenches. The tasks of compacting and confining the waste are done by a team of laborers using simple hand tools such as rakes, shovels, wheelbarrows, hoes, wooden tampers, etc. The tools required depend on the number of laborers and the amount of waste to be buried in the Sanitary Landfill.

**Basic Design Information**

Below are the basic data required for the design of a manual sanitary landfill
Location : Satellite Towns – Gbagalape,
Average total waste generated from 257 respondents : 1091.1kg.
Minimum Design period for landfill: 10 years
Topography : Flat ground
Cover material : 20% of the volume of solid waste compacted
Compaction density of waste: 500kg/m³
Density of waste stabilized in manual landfill: 600kg/m³
Depth of sanitary landfill: 4m
Geometric growth is adopted with a rate of population growth: 2.6%

**A. Projected Population**

$P_f = P_o (1 + r)^n$

Where $P_f$ = Future population, $P_o$ = Present population, r = Rate of population growth
n = Interval in years ($t_{final} - t_{initial}$), t = time variable (in years).

In the first year, $P_1 = 257$

Second year, $P_2 = 257\ (1 + \frac{2.6}{100})^1 = 264$

Third year, $P_3 = 257\ (1 + \frac{2.6}{100})^2 = 271$

And so on

**B. Waste generated per capita per day**

Waste generated per capita per day = $\frac{Weight\ of\ MSW\ generated\ at\ household}{Pop\ x\ 7}$

Where Pop = Total number of householders
Total number of days solid waste was generated = 7
Therefore, weight of MSW generated at household = $\frac{1091.1}{50}$ = 21.82kg

Average number of inhabitants per household = $\frac{257}{50}$ = 5.14, say 5

Therefore, waste generated per capita per day for the 3 socio-economic groups = $\frac{21.82}{5\ x\ 7}$ = 0.623kg/capita/day

It is estimated for each year that production per capita will increase by 0.5% to 1%

For second year, waste generated per capita per day = 0.623 x 1.01 = 0.629 kg/capita/day

Third year, waste generated per capita per day = 0.629 x 1.01 = 0.635 kg/capital/day
And so on

**C. Quantity of solid waste generated**

Daily production of solid waste = Total population x waste generated per capita per day
= 257 x 0.623 = 160 kg/day
Annual production = 160 x 365 = 58,400 kg/yr = 58.40 tons/yr
For second year,
Daily production of solid waste = Total population x waste generated per capita per day
= 257 x 0.629 = 162 kg/day
Annual production = 162 x 365 = 59,130 kg/yr = 59.13 tons/yr
Third year,
Daily production of solid waste = Total population x waste generated per capita per day
= 257 x 0.635 = 163 kg/day
Annual production = 163 x 365 = 59,495 kg/yr = 59.49 tons/yr
And so on.

**Volume of solid waste**

Where daily volume = $\frac{Quantity\ of\ MSW\ generated}{Density\ of\ the\ recently\ compacted\ MSW}$

$= \frac{160}{500} = 0.320$ m³/day

Volume compacted annually = Daily volume x 365
= 0.320 x 365 = 116.8 m³/yr

Volume of stabilized annual waste = $\frac{\text{Quantity of MSW generated}}{\text{Density of stabilized compacted landfill}}$ x 365

$= \frac{160}{600}$ x 365 = 97.3 m³/yr

For second year,

Daily volume = $\frac{Quantity\ of\ MSW\ generated}{Density\ of\ the\ recently\ compacted\ MSW}$

$= \frac{162}{500} = 0.324$ m³/day

Volume compacted annually = Daily volume x 365
= 0.324 x 365 = 118.3 m³/yr

Volume of stabilized annual waste = $\frac{\text{Quantity of MSW generated}}{\text{Density of stabilized compacted landfill}}$ x 365

$= \frac{162}{600}$ x 365 = 98.6 m³/yr

Third year,

Daily volume = $\frac{Quantity\ of\ MSW\ generated}{Density\ of\ the\ recently\ compacted\ MSW}$

$= \frac{163}{500} = 0.326$ m³/day

Volume compacted annually = Daily volume x 365

= 0.326 x 365 = 118.9 $m^3$/yr

Volume of stabilized annual waste = $\frac{\text{Quantity of MSW generated}}{\text{Density of stabilized compacted landfill}}$ x 365

= $\frac{163}{600}$ x 365 = 99.2 $m^3$/yr

And so on.

**Volume of cover material**

Cover material = volume compacted annually x 20%

= 116.8 x 0.2 = 23 $m^3$ of earth/yr

For second year, volume = 118.3 x 0.2 = 24 $m^3$ of earth/yr

Third year, volume = 118.9 x 0.2 = 24 $m^3$ of earth/yr

And so on.

**Volume of Sanitary Landfill**

Volume = volume of annual stabilized + cover material

= 97.3 + 23 = 120.3 $m^3$/yr

For second year, Volume = 98.6 + 24 = 122.6 $m^3$/.yr

Third year, Volume = 99.2 + 24 = 123.2 $m^3$/.yr

And so on

**D. Area required to be filled**

Area to be filled successively = $\frac{\textit{Volume of Sanitary Landfill}}{\textit{Height or Depth of Sanitary Landfill}}$

In the first year, Volume = $\frac{120.3}{4}$ = 30 $m^2$ (3.0 x $10^{-3}$ ha)

Second year, volume = $\frac{122.6}{4}$ = 31 $m^2$ (3.1 x $10^{-3}$ ha)

Third year, volume = $\frac{123.2}{4}$ = 31 $m^2$ (3.1 x $10^{-3}$ ha)

And so on.

**Total Area**

Assume a factor of increase (F) for additional areas to be 30%

For the first year, $A_T$ = F x Area of sanitary landfill

= 1.30 x 30 = 39 $m^2$ (3.9 x $10^{-3}$ ha)

Second year, $A_T$ = F x Area of sanitary landfill

= 1.30 x 31 = 40 $m^2$ (4.0 x $10^{-3}$ ha)

Third year, $A_T$ = F x Area of sanitary landfill

= 1.30 x 31 = 40 $m^2$ (4.0 x $10^{-3}$ ha)

And so on

**E. Calculation of volume of the site using trench method**

Assume a rented excavator has a productivity of 12$m^3$/hour of cut and will work for the duration of 50 days.

Quantity of solid waste produced = 160 kg/day

Quantity of solid waste used as composting = 160 x 0.9 = 144 kg/day

Volume of trench, Vt = $\frac{t \times Qsw \times c.m}{Dsw}$

Where t = time of useful life (days)

Qsw = Quantity of solid waste collected (kg/day)

c.m = cover material (20% of composed volume)

Dsw = Density of the MSW in the landfill (kg/$m^3$)

Therefore, Vt = $\frac{50 \times 144 \times 23}{600}$ = 276 $m^3$

To deposit the SW of one day, it will be necessary to excavate = $\frac{276}{50}$ = 5.5, say 6$m^3$

**Trench dimensions**

Depth, h = 4m

Width, w = 4m

Length, l = ?

But l = $\frac{V}{w \times h}$

Where V = volume of trench

L = length of trench

L = $\frac{276}{4 \times 4}$ = 17.25m, say 17m

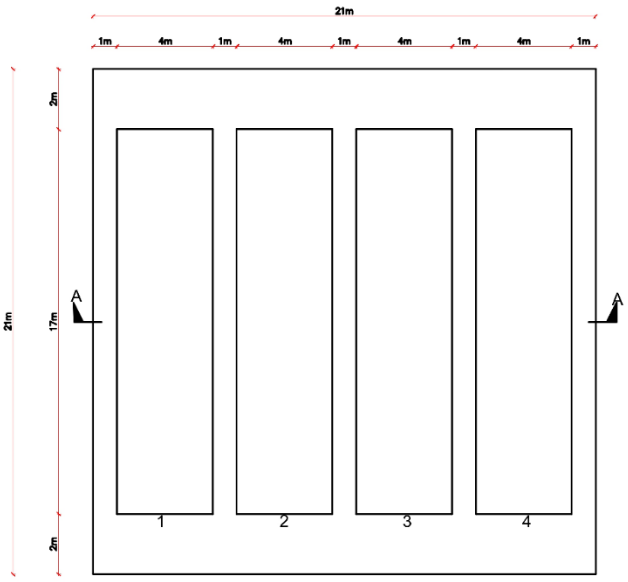


**Figure 1 Trench Layout and Distribution in the Site**

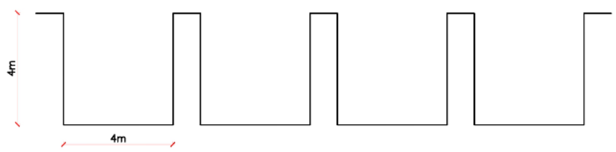


**Figure 2 Section A-A**

**Machinery time**

t = $\frac{V}{R \times J}$

Where t = machinery time for the excavation of trench (days)

V = Volume of trench ($m^3$)

R = Excavation output of the heavy equipment ($m^3$/hr)
J = Daily work days (hours/day)

$$t = \frac{276}{12 \times 8} = 2.8\text{days} \approx 3 \text{ days}$$

This means that 3 days will be required to excavate and make the trench completely ready.

### F. Number of trenches

The site is flat and has an area of 441$m^2$ (Figure 1) The trench occupies a width of 4m. Each trench is separated by a width of 1.0m
That is a total of 5.0m.

Therefore, number of trenches $= \frac{21}{6.0} = 3.5\text{m} \approx 4\text{m}$

### G. Design of daily cell

Assume the labour will operate 6 days a week

### Quantity of waste generated

$$Q_W = \text{Quantity of waste produced per day} \times \frac{7}{\textit{work days in a week}}$$

$$= 160 \times \frac{7}{6} = 187 \text{ kg/working day}$$

### Volume of daily cell

$$V_c = \frac{\text{Quantity of MSW generated}}{\text{Density of MSW compacted in manual sanitary landfill}} \times \text{cover material}$$

$$= \frac{178}{500} \times 23 = 8.6 \text{ m}^3$$

### Dimensions of the daily cell

Area of the cell, $A_c = \frac{V_c}{H_c}$

Where $V_c$ = volume of daily cell ($m^3$)
$H_c$ = height of the cell (m) – limit 1.0 – 1.5m

$$A_c = \frac{8.6}{1} = 8.6 \text{ m}^2\text{/working day}$$

### Length of the cell

Length, $l = \frac{A_c}{w}$

Where w = width – 2m

$$L = \frac{8.6}{2} = 4.3 \text{ m/day} \approx 4\text{m/day}$$

Therefore, l = 4m, w = 2m, h = 1m
This means a square section of cell is chosen.

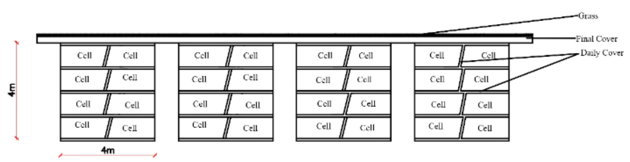


**Figure 3 Sectional View of Daily Cells**

### Waste Generation

Waste generation rate depends on the increase in population growth, local standard of living, consumption patterns, commercial activities, etc. in a community. The residents of Abuja satellite towns presently generate a large amount of solid waste far beyond the management operating capacities of solid waste management system. Table 4 shows the number of households and the waste generated by the residents. A total of 350 samples were collected from the selected 50 households with a population of 257 who generated the total solid waste of 1091.1kg during the one week in June 2021. The quantities of solid waste collected from each socio-economic group were 452.1kg, 394.2kg and 244.8kg respectively. While the amount of the solid waste generated per capita per day was 0.572, 0.599, and 0.699kg/capita/day for low, medium and high-income groups respectively. The average per capita waste generated is 0.623kg/capita/day. The respondents' occupation also determines the kind of wastes being generated in their households with regards to the amount of income they earn monthly.

### Waste Storage

Waste, once generated, is stored at the point of generation for subsequent collection. Waste storage at the point of generation involves storing the waste, until collection by waste contractors engaged by the relevant government agencies, cart pushers ("men shara") or individuals depending on the locations. In High-income group, householders stored their generated waste in plastic bins/containers. They emptied their generated waste stored in these containers into the community/public bins (Roll in Roll out) strategically located in designated areas for onward disposal by the waste contractors. While some respondents usually take their waste to collection point located at Karu cemetery. Householders in the middle-income group are not provided with waste containers. They stored their generated waste in various waste bins and thereafter disposed them in the community bins strategically located within the communities for onward collection and transportation by waste contractors. Householders whose houses are far away from the community bins disposed their waste in open space, and roadsides through Cart pushers who pick the waste from them with a fee. In low-income group, householders are not furnished with storage containers as a result they stored the generated wastes in various containers such as open containers, waste baskets, plastic bags, etc before it is disposed to either open spaces, streets, road sides, rivers, etc.

## Waste Collection

Waste collection is gathering of all waste stored from various sources. In Abuja satellite towns, various waste contractors are engaged by government agencies (STDD and AEPB) to manage waste. In Nyanya ward for instance, the collection and transportation of solid waste is managed by the AEPB, while the other wards like Karu, Orozo, and Karshi are managed by the STDD. In High-income and Middle-income groups, the waste contractors collect the waste stored in community bins and collection point in Karu cemetery, while other communities like Nyanya – Mararaba road axis, the waste are collected from temporary dumping grounds like roadsides, open spaces and streets where the informal sector (cart pushers) popularly known as "men shara" dump the waste collected from households. However, in the Low-income group where the presence of government is not felt in terms of waste management services, wastes indiscriminately dumped in the open space, culverts, drainage lines, and roadsides are left without collection and scattered round where the people including children are seen scavenging for usable waste.

## Waste Transportation

Waste transportation is the movement of the collected waste to disposal sites. In the study area, wastes are transported to dumpsites by various vehicles such as trucks, tippers, and compactor trucks, Roll in Roll out. The waste workers collect waste from the ground and pour it into the trucks till it is filled to it capacity before taking it to disposal sites. The same process is applied using compactor trucks; however the difference is that the compactors compressed/compact the waste and thereafter place it inside the truck. The generated waste stored in Roll in Roll out (RnR) is also transported to dump site with trucks, and thereafter returned back to its original position after disposing the wastes in it. In Low-income areas, where the presence of government is not felt in terms of waste management services, the wastes dumped by the residents in open spaces are left unattended to, thus causing environmental and health risks. The problem is made worse in the rainy season. Solid waste mixed with rain water reduces the aesthetics of the communities.

## Waste Recovery and Recycling

At the moment, there are no working and functioning centers with facilities to recover and recycle solid wastes in Abuja and the entire country in general. Waste recovery and recycling is mainly carried out by the informal sectors such as the cart pushers, waste pickers (scavengers). These people carry out sorting/separation of waste from their carts, community bins, open spaces, collection point in Karu cemetery, and waste vehicles at the dumpsites respectively, thus reducing the quantity of waste to be collected, transported and disposed off. The waste recovered and recycled are thereafter reused directly while some are sold to manufacturing and processing companies who will process the old materials into a new form and other purposes.

## Waste Treatment and Disposal

In the study area and the Federal Capital Territory in general, there are no treatment facility to treat waste or convert it to energy (WtE). Waste is collected from waste storage points and transported straight to disposal sites where open burning is carried out. Waste disposal to dumpsite is usually the final destination of solid waste. There are no engineered/sanitary landfills in Abuja to dispose waste. Wastes are dump by the waste contractors in open dumps with the presence of government officials to monitor and control the process. This is a common practice in Abuja and perhaps the entire country. These wastes are transported to dumpsites from various parts of Abuja. While some residents considered it a cheap way of disposing off their solid wastes by setting the mixed wastes such as clothes, plastics, paper, etc on fire in their backyard or in an open place, thus causing serious and dangerous environmental pollution.

## CONCLUSION

The main obstacles in managing the solid waste in Abuja satellite towns and FCT in general is the scarcity of trucks for moving wastes, non-availability of community bins, abandoning of wastes on drainages and road shoulders which usually sprawl to the road pavement thereby causing traffic and nuisance to humans and the environment, lack of awareness campaigns, sole responsibility of scavengers to recover and recycle waste materials, and others too numerous to mention. With waste openly dumped and sometimes burned within the study area, it is the poor and most vulnerable that is affected. This study has examined the challenges of solid waste management system in Abuja satellite towns. The research was conducted via interviews, field observations, and administration of questionnaires to residents, government officials and waste contractors respectively. The average per capita waste generated in Abuja Satellite towns was 0.623kg/capita/day with 350 samples collected from 257 households that produced 1091.1kg quantity of solid waste. The average household size for all the income levels was 5. Food waste accounted for the highest generated waste across all the income groups, while metals have the least generated waste. The analysis further revealed that respondents' occupation also determines the kind of waste being generated in their households about the amount of income they earn monthly. The design of appropriate waste management is an essential step to avoid future costs from present mismanagement.

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