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ASSESSMENT OF PHYSICOCHEMICAL AND HEAVY METAL PROPERTIES OF SOIL IN AND AROUND GOUSA DUMPSITE, FEDERAL CAPITAL TERRITORY, NIGERIA

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Abstract

The study is aimed at investigating the level of physiochemical and heavy metal properties of the soil around the Gousa dump site and the level of conformity of the physiochemical and heavy metals properties in the soil, with the global and national permissible limits. Primary data source was adopted and 14 soil samples were collected in and around the site from 4 different aligned locations at every 200m radius interval from the heap base of the refuse dump. The samples were collected for top and subsoil horizons across the season. All samples were analysed for physiochemical and heavy metal properties. The results obtained were subjected to the FAO and NESREA limits for soil. The result showed among others a considerable level of heavy metal contamination was recorded in the sampled soils, particularly for Zn (3.1±0.1, 3.3±0.1, 3.3±0, 3.1±0, 3.1±0, 3.1±0, 3.2±0, 3.1±0.1), Cu (0.19±0.0–20.36±0.01 mg/kg and 0.18±0.01–0.31±0.01 mg/kg; dry (0.2±0.01–3.0±0.01 mg/kg and 0.2±0–1.7±1.4 mg/kg) and Fe (4.9±0.01–5.9±0.01 mg/kg and 4.7±0.02–5.5±0.01; 4.9±0–5.9±0 mg/kg to 4.8±0.03–5.7±0.3 mg/kg) against the FAO limits for healthy soil. The soil sample showed statistical variation in the concentration of Zn (0.00<0.05), Cu (0.00<0.05), and Fe (0.0<0.05) against the NESREA limits for both wet and dry seasons, while Cu (0.008<0.05), Fe (0.0<0.05), and Mn (0.0<0.05) showed significant variation with the FAO limit across seasons. The study concluded among others that; the presence of the Gousa dumpsite is contributing to the soil heavy metal pollution such as Zn, Cu, Fe, Mn and Pb against the NESREA and FAO limit. The study recommends among others that a contemporary approach to managing and dealing with waste is necessary, it may entails implementing policies for proper treatment. Furthermore, landfill and waste dump site are attributed to compounding environmental pollution, as such, for an urban city like Abuja, a modern waste management facility aside from dumpsites should be established. This is achievable through public-private partnership agreement.

Key Words: *Dry and wet season, Physiochemical parameters, Heavy metal, concentration, Dump site*

Introduction

Dumpsites are potential sources of various pollutants, including heavy metals, which can contaminate the surrounding environment; soil, water, and plants (Magaji, 2012). The evaluation of biophysical and chemical parameters, as well as heavy metal concentrations is essential to assess the quality of the affected ecosystem and develop appropriate mitigation strategies.

The improper disposal of waste, particularly in dumpsites, can lead to the release of harmful substances into the surrounding environment. Heavy metals, such as lead, cadmium and mercury are of particular concern due to their persistence toxicity and bioaccumulation potential (Idehai and Akujieze, 2016). Their presence in soil, water and plants can have severe ecological and health implications, including soil degradation, water contamination and toxic effects on plants and animals (Breza-Boruta *et al*., 2016). This anaerobic environment negatively affects soil microbial communities, impairing nutrient cycling and organic matter decomposition. As a result, plant nutrient uptake is compromised, leading to nutrient deficiencies and stunted growth.

Furthermore, the physical presence of waste on the land surface can disrupt the natural light penetration, shading plants and inhibiting photosynthesis (Schmidt *et al.,* 2022). The electric conductivity increased upstream and midstream. This could be because of increase in human activities (irrigation farming) upstream and midstream of the sampled stream (Areo, 2023b). Extreme pH levels hinder microbial activity, nutrient availability and plant growth. Additionally, leachate can introduce high concentrations of salts into the soil, leading to soil salinization and further impairing plant health (Kundiri *et al.*, 2017).

These pollutants are potentially hazardous to human health, animals, soil fertility and soil quality. Similarly, the waste impacts the physicochemical properties of the soil, hindering vegetation growth and disrupting normal plant metabolism (Iyebor *et al.,* 2020). The high growth rate and metabolic activity of these microorganisms can, in turn, create detoxification of complex organic molecules into simpler, less toxic compounds (Vincent, 2016). The aim of this study is to determine the level of conformity of physiochemical and heavy metals of soil in and around the Gosa dumpsite to global (FAO/WHO) limits that guarantee environmental safety and sustainability.

Sequel to this aim, the following objectives were pursued: Assessment of seasonal variation of heavy metal concentration in the soil samples in and around the Gousa dumpsite, determination of conformity of physiochemical properties of soil in around the Gousa dunpsite to global (FAO/WHO). Determination of conformity of heavy metal content in the above to global (FAO/WHO).

Study Area

The Gousa dumpsite is located about 10 km off the Nnamdi Azikwe Airport Road, Abuja, Nigeria, within latitude 09°01′173″N - 09°01′270″N of the equator and longitude 07°20′51″ - 07°19′59″E of the Greenwich meridian as shown in Figure 1 (Seidu *et al.,* 2021).

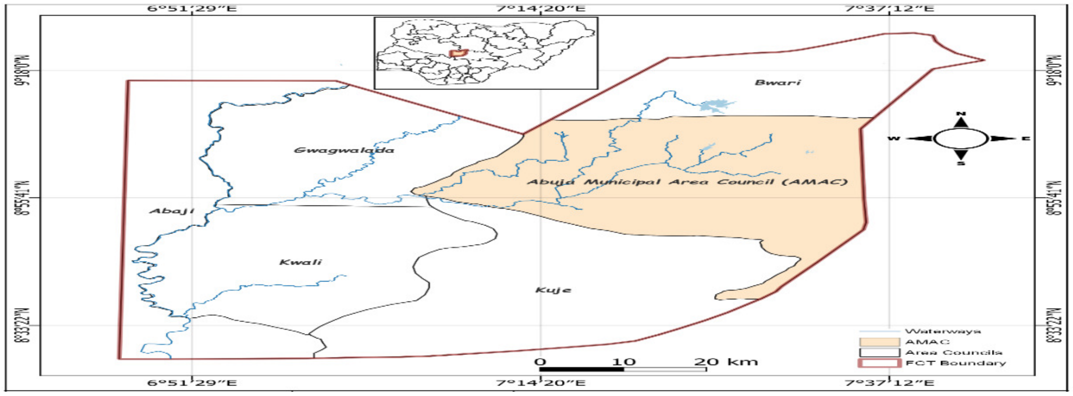

Fig. 1: Map of the Study Area.
Source: Department of Geography and Environmental Management University of Abuja (2023)

Gousa dumpsite is one of the largest and the newest of the four municipal solid waste dumpsites in the Abuja Municipal Area Council. It has a land mass of approximately 90 hectares (222 acres) land. It is an open, uncovered, unlined dumpsite where garbage/waste are dumped which allow "leachate" a liquid formed by decomposing waste, to soaked into the soil and groundwater (Adamu, 2016).

The dominant grass elements include *Andropogon* and *Brachiavia deflexa*. Some dominant tree species of the savannah woodlands yield high-quality timber, e.g., *Anogeissus leiocarpus*, *Daniela oliveri*, *Khaya senegalensis* and *Pterocarpus arenaceous* (Ishaya *et al*., 2016). The climate of Gousa dumpsite is the same as that of Abuja Municipal Area Council, which experiences tropical wet and dry season (Areo, 2023a).

The soil is well decomposed organic matter content in the surface layer; its texture is heavier with depth as the weathered parent material is approached (Ebisintei *et al*., 2015). The soils within this area are generally moist and poorly drained almost all year round and to great extent support farming due to its various natures (Sawyerr *et al*., 2017).

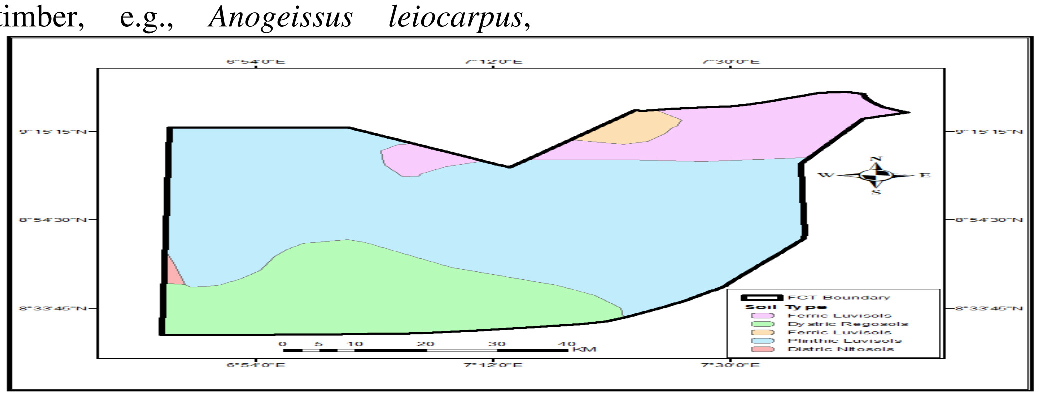

Fig. 2: Soil Type
Source: Food and Agriculture Organization -world soil data (2023)

Materials and Methods

The identification of the point's location of soil samples were taken in dry and wet seasons to ascertain the level of biophysical, chemical parameters and heavy metal pollution on soil in the study area. This design was adopted to draw conclusions in the premise of deductive theory. This study relied on numerical dataset which is most suitable for quantitative analysis. The basic materials and equipment's used in conducting the field exercises are presented thus:

i. Hand Auger was used to collect the soil samples at 0-15cm depth as the top soil and 15- 30cm depth as the subsoil sample.
ii. Foil paper was used to wrap the soil samples collected from the dumpsite.
iii. Masking tape was used to label correctly the soil samples.
iv. Marker was used to number and label the samples.
v. Measuring tape was used for measuring distances beween the soil samples.
vi. Soil thermometer was used to measure the temperature during collection of samples.
vii. Geographical positioning system (GPS aertex)
viii. Sampling box
ix. Writing Pad/Pen

Soil Sample Collection

Soil samples (topsoil and subsoil), were collected randomly from the study area. An imaginery four transect line was drawn from the top of the base of the dumpsite and samples were taken at every 200m radiuas apart. At every radiuas 4 soil sample points (Top Soil 0-15cm and Sub Soil 15-30cm) were picked from North South, South West, East West, South South monthly for six months, in July, August and September for wet season, January, February and March for dry season to sum up to 600m.

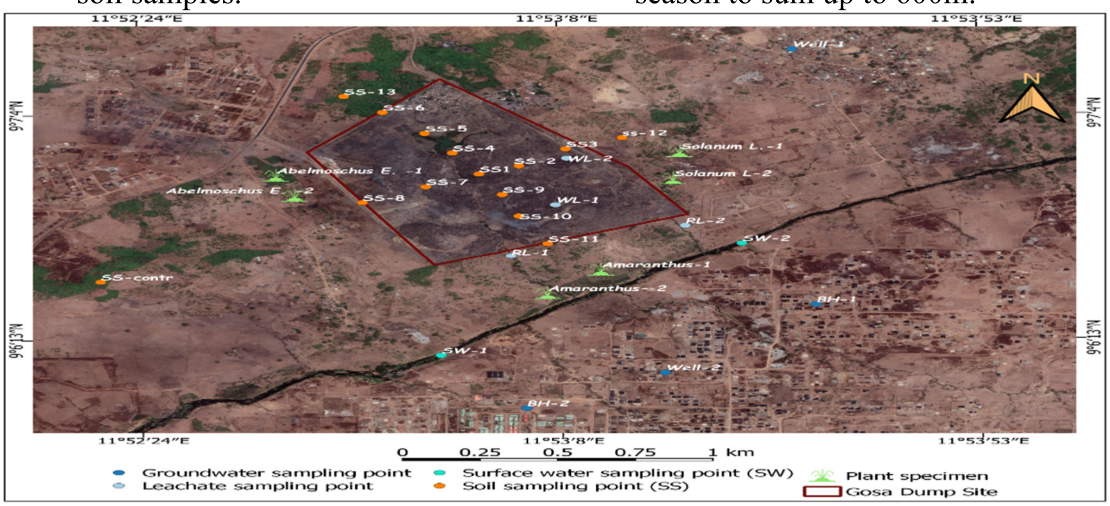

Fig. 3: Sampling location Gousa dumpsite
Source: Department of Geography and Environmental Management University of Abuja (2023)

Soil samples were collected at four different aligned locations at every 200m radius intervals to the base of the refuse dumpsite, at each radius 4 points were marked for soil sample collection at 0-15cm depth for topsoil and 15-30cm depth for subsoil. Also, soil sample was taken 500meters away from the dumpsite to serve as control following standard procedure using auger.

Laboratory Analysis of Samples

Table 1 and 2 shows the analytical methods adopted to assess the physiochemical and heavy metals in the soil samples. The parameters analyzed includes pH, organic carbon, total nitrogen, available phosphorus, sodium, potassium, magnesium, calcium, acidity, cation exchange capacity, bulk density and particles size (soil); Heavy metals such as zinc, copper, iron, manganese and lead were also analysed in the soil samples.

Table 1: The Laboratory Technique for Physiochemical Parameters

Parameters	Soil	Parameters
Sand	Hydrometer and Core	pH, EC.
Silt		EC, TA, TH
Clay		Cl
Bulk Density		
OC	Ph meter ((1: 2.5 soil water and 1:2.5 soil 0.1N KCl), OC (Wetoxidation), TN (Kjehdahl digestion method)	Na, K
TN		Ca, Mg
Ph		
Acidity		
Na+, K+, Mg^{2+}, Ca^{2+}	Na+ & K+ (1N NH4OAc flame photometer), Mg^{2+} & Ca^{2+}Ethelene diamine tetracetic acid (EDTA) and P (Bray II solution)	COD, BOD, DO Sulphate
P		Bicarbonate

Table 2: The Laboratory Technique for Heavy Metals

Parameters	Soil
Mn	Mn, Pb, and Cd were detected by inductively coupled plasma mass spectrometry in a digestion solution
Pb	(ICP-MS; Agilent 7500a,)
Cd	
Fe	Fe was extracted using 10 g soil plus 20 mL of DTPA extractant (diethylene-triamine penta acetic acid) and detected with a flame atomic absorption spectrophotometry (FAAS) in air acetylene (Shimadzu-Tokyo-Japan AA-6300)
Cu	Cu and Zn was detected using atomic absorption spectroscopy fitted with elemental lamps operated at optimum current and wavelengths (AAS Model)
Zn	

Method of Data Analysis

The study adopted both the descriptive and inferential statistical methods of data analysis. The descriptive statistics includes both mean and standard deviation of the derived data obtained from the laboratory analysis (see equation 1 and 2). The equations are presented below:

Mean *eq1*

$$\bar{X} = \frac{\sum X}{N}$$

Where: $\bar{X}$ = Mean

$\sum$ = Summation of the entire data points in the data set

N = Number of data points in the data set

Standard Deviation *eq2*

$$\delta = \sqrt{\sum \frac{(X - \bar{X})^2}{N}}$$

Where: δ = Standard Deviation

$\sum$ = Summation of the entire data points in the data set

X = Value of the ith point in the data set

$\bar{X}$ = The mean value of the data set

N = Number of data points in the data set

Student t-test

The student t-test was adopted to test for differences in the mean concentration of biophysical, chemical and heavy metals in the soil samples with the WHO standard as well as the mean concentration of the same parameters in the plant samples with the FAO standard. See equation 3 for student t-test.

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{(\sigma_1^2/N_1) + \sigma_2^2/N_2}} \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{(\sigma_1^2/N_1) + \sigma_2^2/N_2}} \qquad eq3$$

$\bar{x}_1 \bar{x}_1$ = mean variable one (parameters in the water, soil, and plant)

$\bar{x}_2 \bar{x}_2$ = mean variable two (WHO standard / FAO limit)

$\sigma_1^2 \sigma_1^2$ = the square of the standard deviation of variable one

$\sigma_2^2 \sigma_2^2$ = the square of the standard deviate of variable two

$N_1 N_1$ = total number of values in variable one

$N_2 N_2$ = total number of values in variable two

Results and Discussion

Physiochemical Properties of Soils around Gousa Dump Site

The sampled soils from Gousa Dumpsite were analysed for critical physical and chemical properties to establish the current effect of the waste dumpsite on the soil media. The physical properties of interest analysed in the sampled soils include soil particle size analyses (sand, silt and clay), soil pH, bulk density and organic carbon respectively. These parameters were analysed considering their importance for a healthy soil system.

Particles Size Analysis

Table 3 presents the result of particles size analysis of the sampled soils for both wet and dry seasons. The results showed disparity in the particle size composition of the sampled soils. Accordingly, the wet season samples showed high concentration of sand particles at the average rate of 61±0.8 - 63.05%, followed by clay (19±0.5 - 23±1.7%) and silt (16±0.8 - 19±0.5%) particles respectively for the topsoil. Similarly, the particles size composition of the wet season subsoil samples varied averagely from 61±1.2 - 58±0.5, to 28±0.8 - 21±0.5% and 18±0.8 - 13±0.5% respectively for sand, clay and silt composition. The result indicates high composition of sand and clay particles across the soil horizon during the wet season with slight increase in the sand content at the topsoil compared to the subsoil.

Table 3: Results of Particles Size Analysis of the Sampled Soil

SN	Wet Season					
	Topsoil			Sub Soil		
	Sand	Silt	Clay	Sand	Silt	Clay
Heap Base	61±0.8	18±1.4	21±0.8	61±1.2	18±0.8	21±0.5
200m—EW	62±0.8	18±0.8	20±0	61±0.8	15±0.5	24±1.2
400m—EW	61±0.8	18±0.5	21±0.5	59±0	17±0.5	23±0.8
600m—EW	62±0.5	18±0.8	20±0.5	60±0.8	18±0.5	22±1.2
200m—WW	62±0.8	18±0.9	20±0.5	58±0	17±0.5	25±0.5
400m—WW	62±0.8	18±0.8	20±1.4	61±0.8	16±0.5	23±0.9
600m—WW	63±0.5	18±1.2	20±0.9	60±0.5	16±0.5	25±1.2
200m—NW	63±0.5	18±0.5	19±0.8	60±1.2	17±0.5	23±0.8
400m—NW	60±0.8	18±0.5	23±0	59±0.5	15±0.5	26±0.8
600m—NW	63±0.5	19±0.5	19±0.5	61±0.5	16±0.0	23±0.5
200m—WW	63±0.5	17±0.8	21±1.2	60±0.5	15±0.5	24±0.5
400m—SW	62±0.8	19±0.5	20±0.5	60±0.5	18±0.5	23±0.5
600m—SW	61±0.9	18±0.5	23±0.5	59±1.2	16±0.5	26±0.9
Control	62±0.5	16±0.8	23±1.7	58±0.5	13±0.5	28±0.8
			Dry Season			
Heap Base	62.5±0.5	17.5±0.5	20±0	59±1	15.5±0.5	25.5±0.5
200m—EW	61±0	17.5±0.5	21.5±0.5	59.5±0.5	16±1	24.5±0.5
400m—EW	61±1	19.5±0.5	19.5±0.5	59.5±0.5	17.5±0.5	23±1
600m—EW	61.5±0.5	17.5±0.5	21±0	59±1	16±0	26±0
200m—WW	60.5±0.5	18.5±0.5	21±0	59±2	16±1	25±3
400m—WW	61±2	19±1	20±1	57.5±2.5	17.5±1.5	26±0
600m—WW	61.5±1.5	18.5±0.5	20±2	59±2	19±2	22±0
200m—NW	59±1	18.5±1.5	22.5±0.5	60±1	17.5±2.5	25±1
400m—NW	61.5±1.5	18±0	20.5±01.5	60.5±1.5	17±1	22.5±0.5
600m—NW	62.5±0.5	16.5±0.5	21±0	60.5±0.5	14.5±0.5	25±1
200m—WW	62±0	18±0	20±0	60.5±0.5	18.5±1.5	21±2
400m—SW	61.5±1.5	17±0	21.5±1.5	59.5±0.5	16.5±0.5	24±1
600m—SW	61±0	16.5±1.5	22.5±1.5	59±1	14.5±1.5	26.5±2.5
Control	61±0	18±1	21±1	60.5±0.5	19±1	20.5±0.5

Note: m (distance in meter), EW (Eastward), WW (Westward), NW (Northward), SW (Southward)

The particle size distribution of the dry season soil samples also indicates high concentration of sand particles at the average rate of 59±1 - 62.5±0.5% and 59±1 - 60.5±1.5% for both top and subsoils respectively. This is followed by clay (19.5±0.5 - 22.5±1.5% and 20.5±0.5 - 26.5±2.5) and silt (16.5±0.5 - 19±1 and 14.5±0.5 - 19±1%) as shown in Table 3. The particles size analysis observed in the order of sand>clay>silt across season and horizonal differentials (top and subsoil) indicates that the textural class of the soils in and around Gousa dump site is sandy clay loam (SCL). This textural class may be attributed to parent material from which the soils were formed, thus, implied that the soil particle size properties have not been modified or affected by the presence of the Gosa dump site. This result is similar to the reported findings of Areo (2023) which established that, silt content of the soils under tree land was on the average higher than that of the grassland, although their means were not significantly different. Obianefo *et al.* (2017), also stated that the particles size analysis of soils around selected dumpsites in Port Harcourt were at the range of 76% - 86%, 8% - 17%, and 2% - 8% for sand, clay and silt properties respectively, which is an indication of a sandy clay-loam soil texture.

pH, Bulk Density and Organic Carbon Distribution

The result showed that pH varied on average from 6.3±0.5 - 6.9±0.05 and 6.5±0.05 - 6.9±0.1 for the top and subsoil samples obtained during the wet season. Similarly, the average concentration of pH detected in the dry season samples were at the range of 6.3±0.5 - 6.9±0.05 and 6.5±0.1 - 6.8±0.15 for both top and subsoil samples respectively. The results showed that the concentration of pH in the respective soil samples within the dumpsite and the control point are within the NESREA (6 - 9) and FAO (6.5 - 8.5) limits for a healthy soil.

However, the pH level of the entire soil samples showed slightly acidic soils, with decrease in acidity away from the dump heap. The result of pH levels obtained in this study is positively comparable to the 5.34 - 6.8 reported around solid waste dumpsite in Uyo Metropolis by Ihedioha *et al*. (2017). Elsewhere in Yenagoa, (Tautua *et al*., 2014), reported a neutral to slightly alkaline pH levels around dumpsite soils.

Table 4: Results of pH, BD and OC concentration in the sampled soils

S/N	Wet Season					
	Topsoil			Subsoil		
	Ph (H_2O)	BD (g/cm^3)	OC (%)	Ph (H_2O)	BD (g/cm^3)	OC (%)
Heap Base	6.8±0.1	1.7±0.01	0.3±0.02	6.7±0.0	1.8±0.05	0.3±0.04
200m—EW	6.8±0	1.9±0.01	0.3±0.05	6.7±0.1	1.9±0.01	0.2±0.02
400m—EW	6.7±0.05	1.8±0.01	0.3±0.0	6.8±0.1	1.8±0.02	0.2±0.02
600m—EW	6.7±0.1	1.8±0.01	0.2±0.02	6.6±0.0	1.9±0.01	0.3±0.03
200m—WW	6.9±0	1.7±0.02	0.3±0.02	6.6±0.2	1.7±0.08	0.2±0.01
400m—WW	6.7±0.1	1.9±0.01	0.2±0.02	6.9±0.1	1.9±0.04	0.3±0.07
600m—WW	6.7±0.05	1.8±0.01	0.2±0.01	6.6±0.1	1.9±0.02	0.2±0.06
200m—NW	6.9±0	1.7±0.01	0.3±0.0	6.5±0.05	1.8±0.02	0.2±0.06
400m—NW	6.9±0.05	1.8±0.01	0.3±0.02	6.8±0.05	1.8±0.01	0.2±0.07
600m—NW	6.3±0.5	1.9±0.01	0.3±0.01	6.7±0.15	1.9±0.03	0.3±0.07
200m—SW	6.9±0.05	1.8±0.01	0.3±0.01	6.9±0.05	1.8±0.01	0.3±0.04
400m—SW	6.8±0.05	1.8±0.01	0.3±0.02	6.8±0.1	1.8±0.02	0.2±0.03
600m—SW	6.8±0.1	1.8±0.0	0.2±0.0	6.7±0.05	1.8±0.01	0.2±0.07
Control	6.9±0.05	1.8±0.02	0.3±0.02	6.6±0.0	1.8±0.01	0.2±0.06
			Dry Season			
Heap Base	6.8±0.1	1.89±0.01	0.33±0.02	6.7±0.0	1.88±0.05	0.25±0.04
200m—EW	6.8±0.0	1.80±0.01	0.27±0.05	6.7±0.1	1.82±0.01	0.22±0.02
400m—EW	6.7±0.05	1.81±0.01	0.27±0.0	6.7±0.1	1.85±0.02	0.21±0.02
600m—EW	6.7±0.1	1.72±0.01	0.27±0.02	6.6±0.0	1.76±0.01	0.25±0.03
200m—WW	6.9±0.0	1.82±0.02	0.25±0.02	6.7±0.2	1.81±0.08	0.22±0.01
400m—WW	6.7±0.1	1.81±0.01	0.22±0.02	6.5±0.1	1.83±0.04	0.25±0.07
600m—WW	6.7±0.05	1.72±0.01	0.28±0.01	6.5±0.1	1.78±0.02	0.25±0.06
200m—NW	6.9±0.0	1.79±0.01	0.26±0.0	6.8±0.05	1.81±0.02	0.22±0.06
400m—NW	6.9±0.05	1.87±0.01	0.285±0.02	6.8±0.05	1.87±0.01	0.24±0.07
600m—NW	6.3±0.5	1.74±0.01	0.31±0.01	6.8±0.15	1.77±0.03	0.26±0.07
200m—SW	6.9±0.05	1.79±0.01	0.29±0.01	6.8±0.05	1.81±0.01	0.26±0.04
400m—SW	6.8±0.05	1.77±0.01	0.24±0.02	6.6±0.1	1.78±0.02	0.22±0.03
600m—SW	6.8±0.1	1.80±0.0	0.29±0.0	6.6±0.05	1.82±0.01	0.25±0.07
Control	6.9±0.05	1.72±0.02	0.29±0.02	6.8±0.0	1.75±0.01	0.23±0.06
	Ph		BD		OC	
NESREA	6-9		-		-	
FAO Limit	6.5-8.5		2.65		-	

Note: m (distance in meters), EW (Eastward), WW (Westward), NW (Northward), SW (Southward), BD (Bulk density), OC (Organic carbon)

The average bulk density for the wet season soil samples varied from 1.7±0.01 - 1.9±0.01 g/cm^3 and 1.7±0.08 - 1.9±0.04 g/cm^3 across the sampling point in both top and subsoil respectively. On average, the heap base (1.7±0.01 g/cm^3) and 200m westward (1.7±0.08 g/cm^3) samples showed the lowest observed bulk density in both the top and sub soils during the wet season (Table 4). The average bulk density of the dry season soil samples varied from 1.72±0.01 - 1.89±0.01 g/cm^3 and 1.75±0.01 - 1.88±0.05 g/cm^3 for both top and subsoil samples respectively across the sampling location. The lowest average bulk density of 1.72±0.01 g/cm^3 and 1.75±0.01 g/cm^3 were observed in the samples obtained 600m westward away from the dump heap and the control sites for both top and subsoil respectively. However, the average recorded bulk density across the different sampling location were within 2.65 g/cm^3 recommended by FAO as appropriate for crop root penetration. The result therefore indicates that the bulk density of the soils around Gousa dumpsites is of moderate compaction, which may be attributed to the high rate of sand contents attributed to the parent materials. The results were however not coincidental as (Ihedioha *et al*., 2017) also reported moderate bulk density around municipal waste dump site in Uyo Metropolis at the range of 1.40 - 1.86 g/cm^3. Similarly, (Okeke 2014) reported moderate bulk density within solid waste dump site at the rate of 1.25 - 152 g/cm^3 in the Ferrallitic soils of Owerri, Nigeria.

The average concentration of organic carbon (CO) observed in the sampled soils varied from 0.2±0.0 - 0.3±0.05% to 0.22±0.02 - 0.33±0.02% in the topsoil samples during the wet and dry season respectively, indicating low organic carbon content in the topsoil samples irrespective of seasons across the sampling locations. Similarly, the subsoil samples showed an average organic carbon of 0.2±0.02 - 0.3±0.07% and 0.21±0.02 - 0.26±0.07 % for both wet and dry season respectively. In general, the organic carbon content in the respective sampled soils were low. This is not farfetched from the fact that the solid waste dumped in the study area is void of organic matter components that could potentially enrich the soil media within the dump site. However, this is against the findings of Okeke (2014) in which high OC was reported at the range of 3.20-3.08% in the soils around the solid waste dump site in Owerri. Similarly, (Badmus *et al*., 2014) reported moderate to high (1.87-5.30%) concentrations of OC around dump site locations in Southwest Nigeria, which was attributed to the deposal of solid waste containing organic matter.

Chemical Properties of Sampled Soil around Gosa Dumpsite

Total Nitrogen, Phosphorus, Sodium, Potassium Concentration

The result obtained from the laboratory analysis of the sampled soils showed slight differences in the concentration of these parameters across the sampling locations within the Gosa dump site environment (Table 4). Total nitrogen (TN) was reportedly 0.4±0.0 - 0.5±0.02% and 0.3±0.0 - 0.4±0.01% in the top and subsoil samples obtained during the wet season. The result implied that the concentration of TN decreases with soil depth during the wet season resulting from the illuviation process. Similarly, the subsoil samples showed a decreasing spatial variation of TN in the sampled soils from 0.4±0.0% to within 200m to 400m east, west and northern axis from the dump heap to 0.3±0.0% at 200m to 600m southward.

Similarly, the average TN observed in the dry season samples varied from 0.36±0.01 - 0.45±0.02 and 0.32±0.1 - 0.43±0.0 for both top and subsoils across the sampling locations respectively. The southern axis of the dump heap showed a low concentration of TN compared to the east, west and northern axes which may be resulting from topo-sequence differentials influenced by the dumps. In General, the dump site soils showed a low amount of TN compared to the NESREA (20%) but were in line with the FAO (0.1 - 2%) requirements for optimum soil quality.

Table 5: Results of TN, P, Na^+, and K^+ concentration in the sampled soils

S/N	**Wet Season**							
	Topsoil				Subsoil			
	TN (%)	P (mg/kg^{-1})	Na^+ (Cmol kg^{-1})	K^+	TN (%)	P (mg/kg^{-1})	Na^+ (Cmol kg^{-1})	K^+
Heap Base	0.4±0.01	27.9±0.0	1.74±0.0	1.73±0.02	0.3±0.0	27.9±0.1	1.7±0.01	1.68±0.01
200m—EW	0.4±0.01	26.1±0.0	1.72±0.01	1.72±0.1	0.4±0.0	24.2±0.01	1.7±0.0	1.59±0.01
400m—EW	0.4±0.01	25.2±0.0	1.72±0.0	1.69±0.0	0.4±0.01	25.1±0.01	1.7±0.01	1.62±0.01
600m—EW	0.5±0.02	25.2±0.1	1.71±0.0	1.67±0.1	0.4±0.01	24.3±0.01	1.7±0.0	1.66±0.01
200m—WW	0.4±0.02	27.2±0.0	1.70±0.01	1.69±0.0	0.4±0.0	25.4±0.01	1.6±0.01	1.73±0.01
400m—WW	0.4±0.0	28.2±0.0	1.66±0.02	1.68±0.0	0.4±0.0	26.2±0.01	1.6±0.01	1.65±0.01
600m—WW	0.4±0.01	26.1±0.1	1.68±0.0	1.72±0.1	0.4±0.0	24.9±0.01	1.7±0.01	1.69±0.0
200m—NW	0.4±0.01	28.3±0.0	1.72±0.02	1.63±0.03	0.4±0.0	26.3±0.01	1.7±0.01	1.65±0.1
400m—NW	0.4±0.01	26.5±0.0	1.73±0.0	1.67±0.0	0.4±0.0	25.4±0.05	1.7±0.02	1.67±0.02
600m—NW	0.4±0.0	27.7±0.0	1.72±0.01	1.73±0.01	0.3±0.0	26.7±0.05	1.7±0.01	1.7±0.01
200m—SW	0.4±0.01	28.8±0.0	1.74±0.0	1.71±0.01	0.4±0.0	27.3±0.04	1.6±0.0	1.66±0.01
400m—SW	0.4±0.01	28.6±0.0	1.73±0.02	1.76±0.01	0.3±0.01	26.5±0.1	1.7±0.0	1.74±0.01
600m—SW	0.4±0.03	27.6±0.0	1.74±0.01	1.76±0.0	0.3±0.0	25.5±0.1	1.7±0.02	1.67±0.01
Control	0.4±0.01	28.2±0.0	1.72±0.01	1.79±0.0	0.3±0.01	26.3±0.1	1.7±0.05	1.59±0.01
				Dry Season				
Heap Base	0.45±0.01	26.8±0.0	1.71±0.01	1.60±0.01	0.42±0.0	25.6±1.4	1.69±0.01	1.59±0.0
200m—EW	0.39±0.01	25.6±0.5	1.73±0.01	1.69±0.01	0.39±0.0	24.8±0.3	1.75±0.1	1.64±0.04
400m—EW	0.45±0.02	25±0.0	1.72±0.01	1.68±0.02	0.43±0.0	25.8±1.5	1.74±0.1	1.66±0.0
600m—EW	0.39±0.0	27.6±0.3	1.71±0.02	1.68±0.0	0.39±0.0	25.9±0.4	1.69±0.1	1.70±0.02
200m—WW	0.39±0.01	28.8±0.5	1.66±0.02	1.69±0.01	0.37±0.0	25.8±0.5	1.60±0.01	1.66±0.02
400m—WW	0.41±0.01	27.2±1.2	1.69±0.01	1.72±0.02	0.40±0.0	25.7±0.7	1.65±0.02	1.70±0.01
600m—WW	0.42±0.02	28.8±0.5	1.7±0.0	1.60±0.01	0.39±0.1	27.7±1.3	1.59±0.1	1.59±0.0
200m—NW	0.44±0.02	27±0.5	1.75±0.02	1.69±0.01	0.39±0.0	26.9±1.5	1.75±0.1	1.68±0.0
400m—NW	0.39±0.01	28.7±1.0	1.73±0.02	1.72±0.01	0.35±0.0	26.9±0.1	1.71±0.1	1.70±0.01
600m—NW	0.43±0.01	29.3±0.5	1.76±0.02	1.69±0.0	0.39±0.0	27.6±0.4	1.65±0.04	1.67±0.03
200m—SW	0.38±0.01	28.6±0.02	1.72±0.02	1.77±0.01	0.35±0.1	27.6±1.1	1.80±0.1	1.75±0.02
400m—SW	0.40±0.01	27.7±0.1	1.74±0.0	1.76±0.01	0.35±0.0	27.4±2.0	1.78±0.1	1.70±0.1
600m—SW	0.36±0.01	28.5±0.4	1.73±0.01	1.80±0.01	0.32±0.1	27.4±1.3	1.81±0.1	1.69±0.1
Control	0.37±0.01	28.9±1	1.75±0.01	1.75±0.04	0.35±0.2	28.2±0.4	1.76±0.1	1.69±0.04
	TN		P		Na		K	
NESREA	20		<100		0.7—1.2		0.6—1.2	
FAO Limit	0.1—2		10—20		0.7—1.5		0.6—1.2	

Note: m (distance in meter), EW (Eastward), WW (Westward), NW (Northward), SW (Southward), TN (total nitrogen), P (phosphorus), Na^+ (sodium ions) and K^+ (potassium ions)

The low rate of TN recorded far below the NESREA limits is because the potential for nitrogen fixation in the soils has been inhibited by the waste dump. This result is in consonance with the findings of (Ideriah *et al*., 2006) and (Obianefo *et al*., 2017) in which the concentrations of TN around waste dumpsite in Port Harcourt city ranges from 0.02 - 0.1% and 0.11 - 0.7% respectively.

The Phosphorus (P) constituents of the sampled soils during the wet season varied averagely from 25.2±0.0 - 28.8±0.0 mg/kg^{-1} and 24.2±0.01 - 27.9±0.1 mg/kg^{-1} in both the top and subsoils across the sampling locations around the Gousa dumpsite as well as the control points. Similarly, the average values of P in the dry season samples varied from 29.3±0.5 - 25±0.0 mg/kg^{-1} in the topsoil horizon to 24.8±0.3 - 27.7±1.3 mg/kg^{-1} in the subsoil horizon across the sampling locations around Gousa dumpsites as well as the control point respectively. The concentration of P however decreases with an increase in soil depths, which may be attributed to the decomposition of solid waste from food garbage noticed within the topsoil layer. The results showed slight elevation above the FAO limits (10 - 20 mg/kg^{-1}) but well within the NESREA (<100 mg/kg^{-1}) for soil mineral requirements. This indicates adequate enrichment of P in the soils around the Gousa dumpsite and its environs. Similarly, an elevated concentration of (8900 mg/kg^{-1}) above the soil mineral requirement for plant growth was reported around dump sites in Ondo State (Akintola *et al*., 2021).

Sodium ions (Na^+) were at the average rate of 1.66±0.02 - 1.74±0.01 Cmol kg^{-1} and 1.6±0.0 - 1.7±0.01 Cmol kg^{-1} in the top and subsoil samples obtained during the wet season across the Gousa dumpsite and the control. In the dry season samples, the concentration of Na^+ varied averagely from 1.66±0.02 - 1.75±0.01 Cmol kg^{-1} in the topsoil samples and 5.9±0.1 - 1.81±0.1 Cmol kg^{-1} in the subsoil samples respectively irrespective of proximity to the dump heap as well as the control site. The lowest value of Na^+ was observed in the sampled soils (1.66±0.02 ±0.01 - 1.6±0.01 Cmol kg^{-1} and1.66±0.02 - 1.60±0.01 Cmol kg^{-1}) from the westward axis compared to other locations and the control point. The results were all within the NESREA (0.7 - 1.2 Cmol kg^{-1}) limits for the maximum soil requirement of Na^+ for plant growths but were above the FAO limits of 0.7 - 1.2 Cmol kg^{-1}. This indicates adequate enrichment of Na^+ in the sampled soils from the study area. The increasing rate of Na^+ may be attributed to aerosol-containing sodium substances such as plastic wastes from agricultural, food and medicinal products, which are all heaped at the dumpsite without proper sorting from points of generation. The results are not farfetched from the reported claim by (Akinbile *et al*., 2016), in which Na^+ was found at the average range of 7.73 ± 0.06 - 12.06 ± 0.17 Cmol kg^{-1} around the dumpsite in the FUTA campus, which are above the NESREA and FAO limit.

The values of potassium (K^+) in the sampled soils varied slightly with distance away from the heap base as shown in Table 5. While the values of K^+ varied from 1.73±0.02 - 1.68±0.01 Cmol kg^{-1} in the top and subsoil samples obtained from the heap base during the wet season, a decreasing order was recorded in the sampled soils away from the heap base at the average range of 1.63±0.03 - 1.73±0.01 Cmol kg^{-1} and 1.59±0.01 - 1.73±0.01 Cmol kg^{-1} for both top and subsoil samples with the exception of the top and subsoil samples obtained at 400m (1.76±0.01 - 1.74±0.01 Cmol kg^{-1}) and 600m (1.76±0.0 - 1.67±0.01 Cmol kg^{-1}) southward from the heap base. Similarly, the control point showed a high value of K^+ in the topsoil samples at the average of 1.79±0.0 Cmol kg^{-1} compared to the subsoil samples 1.59±0.01 Cmol kg^{-1}. The dry-season soil samples showed a slight decrease in the value of K^+ at the rate of 1.60±0.01 - 1.72±0.01 Cmol kg^{-1} in the topsoil samples with the exception of the samples obtained from the southward axis (1.76±0.01 - 1.80±0.01 Cmol kg^{-1}) and the control site (1.75±0.04 Cmol kg^{-1}). In contrast, the concentration of K^+ in the subsoil samples stood at the average range of 1.59±0.0 - 1.75±0.02 Cmol kg^{-1} across all sampling locations including the control points, which is an indication of a decreasing concentration of K^+ with an increase in soil depth. The results were within the NESREA and FAO limit (0.6 - 1.2) for the optimum soil requirement of K^+. A similar increase in the value of K^+ was reported at the average range of 8.24 ±0.23 - 19.20 ± 0.20 mg/kg within the selected dumpsite areas in Ondo State (Akinbile *et al.,* 2016). Similar to the study of Areo (2023 b) the tree crops had higher mean values of organic matter (2.4% - 4.8%) while the highest value (6.3%) was under cultivation. The decrease observed under grassland (maize cultivation) is an indication that the values of organic carbon, which is used in the determination of organic matter, also decreased lowering the soil quality.

Magnesium, Calcium, Exchangeable Acidity and CEC

As presented in Table 6, the average concentration of Mg^{2+} in the sampled soils varied from 3.4±0.05 - 4.4±0.01 Cmol kg^{-1} and 3.3±0.01 - 4.3±0.02 Cmol kg^{-1} for both top and subsoils obtained during the wet seasons across the sampling locations within the Gousa dumpsite and the control. Similarly, the dry season samples showed an average concentration of Mg^{2+} at the rate of 3.3±0.1 - 4.4±0.01 Cmol kg^{-1} and 3.3±0.0 - 4.2±0.1 Cmol kg^{-1} for both top and subsoil samples respective. The result revealed a slight decrease of Mg^{2+} in the dry season soil samples compared to the wet season samples with elevated levels observed in the topsoil samples.

Similarly, sampled soils from 400m (4.4±0.01 - 4.3±0.02 Cmol kg^{-1} and 4.2±0.01 - 4.1±0.01 Cmol kg^{-1}) and 600m (4.3±0.02 - 4.12±0.02 Cmol kg^{-1} and 4.0±0.0 - 4.0±0.1 Cmol kg^{-1}) southward of the heap base also showed a high amount of Mg^{2+} for both wet season top and subsoils respectively. The concentration of Mg^{2+} detected in the soil samples from the respective locations within the Gousa dumpsite and the control site for both seasons irrespective of horizontal differentials were within the optimum requirement for agricultural soils established by FAO (<5) and the NESREA (3 - 8 Cmol kg^{-1}) respectively. Thus, the waste heap has little to no effects on the Mg^{2+} mineral nutrients of the soils within the dumpsite and the immediate environs. This is similar to the findings of 1.19±0.09 - 1.25±0.06 Cmol kg^{-1} reported by (Akinbile *et al.*, 2016) in FUTA Campus, Ondo State, and 2.2±0.3 - 5.1±0.0 Cmol kg^{-1} posited by (Sawyerr *et al.*, 2017) for dumpsite soils in the FCT.

Table 6: Results of Mg^{2+}, C^{2+}, Ex.A, & CEC concentration in the sampled soils

S/N	**Wet Season**							
	Topsoil				Subsoil			
	Mg^{2+}	C^{2+}	Ex.A	CEC	Mg^{2+}	C^{2+}	Ex.A	CEC
				(Cmol kg^{-1})				
Heap Base	3.4±0.06	4.88±0.0	0.82±0.01	12.5±0.1	3.4±0.03	4.83±0.01	0.8±0.01	11.4±0.02
200m—EW	3.9±0.0	4.86±0.01	0.81±0.0	12.8±0.0	3.9±0.01	4.83±0.03	0.8±0.01	13.6±0.05
400m—EW	3.4±0.05	4.85±0.01	0.83±0.0	12.4±0.1	3.3±0.01	4.84±0.02	0.9±0.01	12.3±0.05
600m—EW	3.9±0.0	4.87±0.01	0.81±0.01	12.9±0.03	3.9±0.01	4.86±0.02	0.8±0.01	12.9±0.01
200m—WW	4.2±0.04	5.29±0.1	0.82±0.0	13.5±0.1	4.0±0.03	5.15±0.03	0.9±0.01	13.3±0.01
400m—WW	3.8±0.1	4.83±0.01	0.80±0.0	12.7±0.1	3.7±0.01	4.73±0.02	0.8±0.01	14.5±0.01
600m—WW	3.8±0.02	4.86±0.01	0.80±0.0	12.8±0.01	3.9±0.01	4.80±0.04	0.8±0.01	12.9±0.02
200m—NW	4.0±0.01	4.86±0.01	0.81±0.1	12.9±0.0	3.9±0.01	4.83±0.03	0.8±0.01	12.8±0.01
400m—NW	3.8±0.02	4.69±0.0	0.79±0.0	12.7±0.0	3.7±0.01	4.63±0.01	0.8±0.0	12.5±0.1
600m—NW	3.9±0.0	4.88±0.0	0.80±0.0	13.1±0.1	3.9±0.01	4.84±0.01	0.8±0.01	12.9±0.01
200m—SW	3.8±0.02	4.78±0.01	0.80±0.0	12.7±0.01	3.7±0.01	4.73±0.01	0.8±0.01	12.5±0.1
400m—SW	4.4±0.01	4.88±0.01	0.80±0.0	13.6±0.1	4.3±0.02	4.84±0.01	0.8±0.01	13.4±0.1
600m—SW	4.3±0.02	5.45±0.03	0.81±0.0	14.0±0.01	4.1±0.02	5.23±0.02	0.8±0.01	13.4±0.05
Control	4.0±0.02	4.85±0.03	0.81±0.1	12.1±0.01	3.9±0.01	4.82±0.01	0.8±0.02	12.9±0.01
				Dry Season				
Heap Base	3.9±0.0	4.87±0.02	0.82±0.02	12.8±0.0	3.8±0.1	4.79±0.02	0.82±0.02	13.1±0.5
200m—EW	3.3±0.1	4.86±0.02	0.83±0.03	12.4±0.0	3.3±0.0	4.82±0.01	0.84±0.03	12.3±0.1
400m—EW	3.9±0.0	4.87±0.0	0.81±0.01	12.9±0.0	3.8±0.1	4.78±0.1	0.81±0.01	12.8±0.1
600m—EW	4.2±0.1	5.17±0.01	0.84±0.03	13.5±0.0	4.1±0.1	5.16±0.04	0.85±0.03	13.4±0.2
200m—WW	3.7±0.0	4.83±0.0	0.80±0.01	12.6±0.0	3.7±0.0	4.63±0.1	0.81±0.01	13.4±1.1
400m—WW	3.8±0.01	4.84±0.0	0.80±0.0	12.8±0.0	3.8±0.1	4.74±0.1	0.82±0.0	12.7±0.2
600m—WW	4.0±0.0	4.85±0.01	0.81±0.02	12.9±0.0	4.0±0.1	4.79±0.02	0.82±0.02	12.8±0.1
200m—NW	3.8±0.0	4.68±0.0	0.79±0.01	12.7±0.0	3.8±0.1	4.66±0.04	0.80±0.01	12.7±0.2
400m—NW	3.9±0.0	4.89±0.0	0.80±0.0	13.0±0.0	4.0±0.1	4.81±0.04	0.82±0.0	13.0±0.1
600m—NW	3.8±0.01	4.78±0.01	0.81±0.01	17.8±5.0	3.7±0.01	4.69±0.03	0.81±0.01	12.5±0.02
200m—SW	4.4±0.01	4.87±0.0	0.82±0.01	13.5±0.0	4.2±0.1	4.80±0.04	0.82±0.01	13.3±0.04
400m—SW	4.2±0.01	5.42±0.0	0.82±0.02	18.9±5.0	4.1±0.01	5.27±0.1	0.82±0.02	13.6±0.3
600m—SW	4.0±0.0	4.83±0.02	0.81±0.0	12.1±0.0	4.0±0.1	4.73±0.1	0.82±0.0	13.0±0.2
Control	3.3±0.03	4.87±0.0	0.81±0.01	12.4±0.0	3.4±0.04	4.81±0.02	0.81±0.01	12.0±0.6
	Mg^{2+}		C^{2+}		Ex. A		CEC	
NESREA	3-—8		10—20		-		2	
FAO Limit	<5		10—50		-		10	

Note: m (distance in meter), EW (Eastward), WW (Westward), NW (Northward), SW (Southward), Mg^{2+} (magnesium), C^{2+} (calcium), Ex. A (exchangeable acidity) and CEC (cation exchange capacity).

The concentration of C^{2+} varied averagely from 4.69±0.0 - 5.45±0.03 Cmol kg^{-1} and 4.73±0.01 - 5.23±0.02 Cmol kg^{-1} in both top and subsoil samples obtained during the wet season, while the dry season samples showed average concentration of C^{2+} at the range of 4.68±0.0 - 5.42±0.0 Cmol kg^{-1} and 4.66±0.04 - 5.27±0.1 Cmol kg^{-1} for both the top and subsoil samples obtained within the Gousa dumpsite and the controlled point respectively. The highest level of C^{2+} was detected in the sampled soils obtained at 600m southwest axis (5.45±0.03 - 5.23±0.02 Cmol kg^{-1}) and 600m eastward (5.17±0.01 - 5.16±0.04 Cmol kg^{-1}) of the waste dump during the wet and dry season respectively. Despite that, the soils showed considerable C^{2+} across the sampled locations irrespective of season and horizons, the values were below the NESREA (10 - 20 Cmol kg^{-1}) and FAO (10 - 50 Cmol kg^{-1}) optimum requirement for a healthy soil nutrient. The findings agreed with the observations of Ogbuehi *et al.* (2021). They reported low concentrations of C^{2+} (0.1026 - 3.20 Cmol kg^{-1}) in the soils around the municipal waste dump site in Owerri Metropolis.

The exchangeable acidity content of the sampled soils during the wet (0.79±0.0 - 0.82±0.0 Cmol kg^{-1} and 0.8±0.01 - 0.9±0.01 Cmol kg^{-1}) and dry (0.79±0.01 - 0.84±0.03 Cmol kg^{-1} and 0.80±0.01 - 0.85±0.03 Cmol kg^{-1}) season samples obtained from both top and subsoil horizon in the respective locations within the Gousa dumpsite and the controlled point showed slight differences respectively. The highest exchangeable acidity was detected in the soils sampled 400m eastward (0.83±0.0 - 0.9±0.01 Cmol kg^{-1}) of the waste dump in the wet season and 600m eastward (0.84±0.03 - 0.85±0.03 Cmol kg^{-1}) in the dry season respectively. The result indicates a moderate exchangeable acidity concentration in relation to the CEC of the samples (Table 6).

The combined mineral ions that constitute the CEC as shown in Table 6 indicate high accumulation of ions nutrient in the sampled soils within the Gousa dumpsite and the control point respectively. Accordingly, the average concentration of CEC in the sampled soils during the wet season varied from 12.4±0.1 - 14.0±0.01 Cmol kg^{-1} in the topsoils to 11.4±0.02 - 14.5±0.01 Cmol kg^{-1} in the subsoil samples across the respective sampling locations within the dump site and the controlled point. The result showed elevated CEC at the southwestern part of the dump heap across the horizon during the wet season. In the dry season, the average CEC varied from 12.1±0.0 - 18.9±5.0 Cmol kg^{-1} and 12.0±0.6 - 13.4±0.2 Cmol kg^{-1} for both top and subsoil samples obtained within the dumpsite and the control during the dry season. The results indicate a high amount of CEC in the sampled soils above the NESREA (2 Cmol kg^{-1}) and FAO (10 Cmol kg^{-1}) limits for healthy soils.

Heavy Metal Pollution in the Soils around Gosa Dump Site

Traces of heavy metals were detected in the sampled soils within and around the Gousa dumpsite as shown in Table 7. The result showed that the average concentration of Zn varied from 2.9±0 - 3.3±0.1 mg/kg (topsoil) to 2.9±.01 - 3±0.01 mg/kg (subsoil) during the wet season, while the dry season samples showed similar variation in the value of Zn in the topsoil (2.9±0.02 - 3.3±0.02 mg/kg) and subsoil (2.9±0.1 - 3.2±0.2 mg/kg) samples respectively. The result showed that the average concentration of Zn detected in the sampled soils during the wet and dry season across horizons are within the NESREA limit of 5 mg/kg. In contrast, sampled soils (topsoil) at the heap base, 200m eastward, 600m eastward, 600 westwards, 400m northward, 600m northward, 200m and 400m southward (3.1±0.1, 3.3±0.1, 3.3±0, 3.1±0, 3.1±0, 3.1±0, 3.2±0, 3.1±0.1) showed elevated Zn concentration above the FAO limit of 3.0 mg/kg. Similarly, the concentration of Zn in the dry season samples also showed elevated levels above the FAO limit except for the samples obtained at proximately 200m - WW, 600m - WW, 400m - SW and 600m - SW of the dumpsite. The high rate of Zn in the sampled soils is tantamount to the several waste streams dumped in the landfill without proper sorting and segregation. This may also result in an imbalance of mineral nutrients in the soil, with adjoining being the major receptor at the advent of leaching in farmland. This result is similar to the findings of (Sawyerr *et. al*., 2017) in the satellite towns of the FCT. They observed traces of Zn across dumpsites in Bwari, Kuje, Gwagwalada and AMAC at the rate of 1.8±0.4, 0.7±0.4, 1.1±0.1 and 1.4±0.3 mg/kg and attributed the result to varying properties of wastes across the landfill sites.

Table 7: Results of heavy metal concentration (Zn, Cu, Fe, Mn and Pb) in the sampled soils

S/N	**Wet Season**									
	Topsoil					Subsoil				
	Zn	Cu	Fe	Mn	Pb	Zn	Cu	Fe	Mn	Pb
	mg/kg									
Heap Base	3.1±0.1	0.34±0.01	5.0±0.01	0.9±0.01	1.06±1.5	3±0.01	0.2±0	5.4±0	0.76±0	0.01±0
200m—EW	3.3±0.1	0.27±0.01	5.9±0.01	0.8±0.01	0.04±0.0	3±0.01	0.18±0.01	4.7±0.02	0.79±0	0.01±0
400m—EW	3.0±0.1	0.19±0.02	4.9±0.01	0.8±0.01	0.02±0.0	3±0.01	0.22±0.01	5.2±0	0.77±0	0.01±0
600m—EW	3.3±0	0.26±0.01	5.4±0.02	0.8±0.01	0.02±0.0	2.9±.01	0.18±0.01	5.2±0	0.67±0.01	0.00±0
200m—WW	3.0±0	0.28±0.01	5.3±0.01	0.7±0.01	0.01±0.0	3±0.01	0.31±0	5.0±0.01	0.76±0	0.01±0
400m—WW	3.0±0	0.33±0.01	5.0±0.01	0.8±0	0.01±0.0	3±0	0.31±0.01	5.2±0	0.84±0.01	0.01±0
600m—WW	3.1±0	0.34±.01	5.3±0.01	0.9±0.01	0.01±0.0	2.9±0.02	0.27±0.01	5.0±0.02	0.86±0.02	0.02±0
200m—NW	3.0±0	0.28±.01	5.1±0	0.9±0.01	0.02±0.0	2.9±0.02	0.30±0	5.5±0.01	0.86±0.02	0.01±0
400m—NW	3.1±0	0.34±.02	5.6±0	0.9±0.01	0.01±0.0	3±0	0.27±0.01	5.1±0.01	0.90±0	0.01±0
600m—NW	3.1±0	0.28±0.01	5.1±0.02	0.9±0.01	0.02±0.0	3±0	0.30±0.02	5.0±0.02	0.85±0.02	0.01±0
200m—SW	3.2±0	0.32±0.01	5.1±0.03	0.9±0.01	0.01±0.0	3±0.01	0.32±0.01	5.0±0.01	0.82±0.01	0.02±0
400m—SW	3.1±0.1	0.36±0.01	5.0±.01	0.8±0	0.01±0.0	2.9±0.01	0.27±0.03	5.1±0.01	0.90±0	0.01±0
600m—SW	3.0±0	3.02±0	5.2±.01	0.9±0	0.01±0.0	2.9±0.01	0.27±0	5.2±0	0.82±0.01	0.01±0
Control	2.9±0	0.29±0	5.2±.01	0.8±0	0.01±0.0	3±0	0.31±0.01	5.0±0	0.92±0	0.01±0
	Dry Season									
Heap Base	3.3±0.01	0.3±0.01	5.9±0	0.8±0	0.01±0	3.1±0.11	0.3±0.04	5.7±0.3	0.8±0.02	0.01±0
200m—EW	3.1±0.1	0.2±0.01	4.9±0	0.8±0	0.01±0	3.0±0.01	0.2±0	4.8±0.03	0.8±0	0.01±0
400m—EW	3.3±0.02	0.3±0.01	5.4±0	0.8±0	0.01±0	3.2±0.2	0.3±0.03	5.4±0.2	0.8±0.02	0.01±0
600m—EW	3.1±0.1	0.3±0	5.3±0	0.7±0	0±0	3.0±0.1	0.2±0.04	5.3±0.1	0.7±0.02	0.00±0
200m—WW	3.0±0.00	0.3±0.02	5.0±0	0.8±0	0±0	3.0±0.02	0.3±0.02	5.0±0.1	0.8±0.01	0.01±0
400m—WW	3.1±0.01	0.3±0	5.3±0	0.9±0	0.01±0	3.1±0.04	0.3±0.02	5.3±0.1	0.9±0.02	0.01±0
600m—WW	3.0±0.01	1.7±1.2	5.1±0	0.9±0	0.02±0	2.9±0.1	0.3±0.01	5.1±0.1	0.9±0.01	0.02±0
200m—NW	3.1±0.01	0.4±0.01	5.6±0	0.9±0	0.01±0	3.0±0.1	0.3±0.01	5.6±0.02	0.9±0	0.01±0
400m—NW	3.1±0.02	1.6±1.4	5.1±0	0.9±0	0±0	3.1±0.1	0.3±0.01	5.1±0.04	0.9±0.01	0.00±0
600m—NW	3.2±0.01	0.3±0.01	5.1±0	0.9±0	0±0	3.1±0.1	0.3±0.01	5.1±0.1	0.9±0	0.01±0
200m—SW	3.1±0.02	0.4±0	5.0±0	0.9±0	0.01±0	3.0±0.02	0.3±0.01	5.0±0.01	0.9±0.01	0.02±0
400m—SW	3.0±0	3.0±0.01	5.2±0	0.9±0	0±0	2.9±0.1	1.7±1.4	5.2±0.03	0.9±0.03	0.00±0
600m—SW	2.9±0.02	0.3±0	5.3±0	0.9±0	0.01±0	3.0±0.1	0.3±0.02	5.3±0.03	0.8±0	0.01±0
Control	3.1±0.02	0.3±0.01	5.0±0	0.9±0	0.02±0	3.1±0.1	0.3±0	5.0±0.2	0.9±0.03	0.01±0
	Zn	Cu	Fe	Mn	Pb					
NESREA	5.0	1.5	2.0		0.1					
FAO	3.0	0.1	0.3	0.2	0.05					

Note: m (distance in meters), EW (Eastward), WW (Westward), NW (Northward), SW (Southward), Zn (zinc), Cu (copper), Fe (iron), Mn (manganese) and Pb (lead)

The average concentration of Cu in the wet season soil samples ranged from 0.19±0.0 - 20.36±0.01 mg/kg and 0.18±0.01 - 0.31±0.01 mg/kg for both top and subsoil horizons across the dumpsite and the control. The values were all above the FAO (0.1 mg/kg). In contrast, all the results were within the NESREA (1.5 mg/kg) limit except for the samples obtained at 600m southward (3.02±0 mg//kg). The dry season samples also showed the average variation of 0.2±0.01 - 3.0±0.01 mg/kg and 0.2±0 - 1.7±1.4 mg/kg across the soil horizon (top and subsoil) within the dumpsite and the control (0.3±0.01 - 0.3±0.01 mg/kg). The values are all above the FAO limit (0.1 mg/kg) but conform to the NESREA limit (1.5 mg/kg) except for the sampled soils within 600m - WW (1.7±1.2 mg/kg), 400m - NW (1.6±1.4 mg/kg) and 400m - SW (3.0±0.01 mg/kg) for the topsoil samples and 400m - SW (1.7±1.4 mg/kg) for the subsoil. The result signified changes in the vertical decrease of Cu across the sampling locations within the Gousa dumpsites, thus at par with the reported findings of 0.01 - 1.04 mg/kg in the Mpape dumpsite by (Magaji and Mallo, 2020). Similarly, soils around the dumpsite in Kuje and Kwali Area Council of the FCT reportedly showed elevated levels of Cu (46.88 ± 11.67 mg/kg and 65.69 ± 10.50 mg/kg) attributed to the landfill (Ojiego *et al.*, 2022).

Traces of Fe detected in the wet season samples varied averagely from 4.9±0.01 - 5.9±0.01 mg/kg and 4.7±0.02 - 5.5±0.01 mg/kg for both top and subsoils across the Gousa dumpsite and the control point. The average rate of Fe in the dry season samples varied from 4.9±0 - 5.9±0 mg/kg to 4.8±0.03 - 5.7±0.3 mg/kg for both top and subsoils across the Gousa dumpsite and the control point. The result showed elevated levels of Fe in the dry-season subsoil samples compared to the wet-season samples. Similarly, the values of Fe detected across the spatial location within the dumpsite and the control were far above the FAO (0.3 mg/kg) and NESREA (2.0 mg/kg) limit for healthy soil, indicating elevated levels of Fe contamination. This is not surprising as previous studies have observed similar traits of Fe around dumpsites in Abakaliki, Owerri, Nnewi, and Aba at the rate of 31154±5550.89 - 90365.5±33195.17 mg/kg (Onwukeme and Eze, 2021), and at the range of 66.67±2.81 - 713.27±16.62 mg/kg across five municipal waste dumpsites in Umuahia (Nnaji and Chukwu, 2020).

Traces of Mn and Pb were also detected in the sampled soils irrespective of horizon, spatial differential and season. As shown in Table 7 the concentration of Mn varied averagely from 0.7±0.01 - 0.9±0.01 mg/kg and 0.67±0.01 - 0.92±0 mg/kg for both top and subsoil samples during the wet season; and 0.7±0 - 0.9±0 and 0.7±0.02 - 0.9±0.03 mg/kg for the dry season samples across all locations including the control. The values were far above the 0.2 mg/kg recommended by FAO. In contrast, the concentration of Pb in the sampled soil during the wet (0.01±0.0 - 1.06±1.5 mg/kg and 0.01±0 - 0.02±0 mg/kg) and dry (0.0±0 - 02±0 mg/kg and 0.0±0 - 0.02±0.01 mg/kg) season were within the NESREA (0.1 mg/kg) and FAO (0.05 mg/kg), except for the concentration of Pb in the topsoil samples at the heap base (1.06±1.5 mg/kg) of the Gousa dumpsite. The result suggests that the unlined waste dumpsite (Gousa) has an impact on the accumulation of Pb in the soils which decreases outwardly in relation to spatial proximity. This is in conformity with the findings of (Nnaji and Chukwu, 2020). They reported an accumulated spatial decrease of Pb in the order of 8.72±0.84 - 12.47± at zero distance from dumpsites to 1.21mg/kg to 1.11±0.04 - 2.01±0.03 mg/kg at 10m distance in Southeast Nigeria.

Variation Test of Soil Physiochemical and Heavy Metals Content to Established NESREA and FAO Limits

The cumulative average concentration of the physiochemical and heavy metal contents in the sampled soils around the Gousa dumpsite was subjected to the student t-test analysis to ascertain the rate of variation and conformity to NESREA / FAO permissible limit (Table 8).

The result presented in Table 4.12 indicates that the concentration of pH, TN, P, Na, K, Mg^{2+}, C^{2+} and CEC in the sampled soils during the wet and dry season showed significant variation with the NESREA and FAO for soil quality given by the p-value of 0.00<0.05. Similarly, the BD of the sampled soils showed statistical variation with the FAO limit (0.0<0.05). Heavy metal concentrations such as Zn (0.00<0.05), Cu (0.00<0.05), and Fe (0.0<0.05), showed statistical variation with the NESREA limits for both wet and dry seasons, while Pb (0.0<0.05) only showed statistical difference in the dry season samples to NESREA limits.

Table 8: Variation of physiochemical and heavy metal accumulation in the soil samples to established NESREA and FAO limits

Parameters	Horizon	NESREA			FAO	
		df	t. stat	P-value	t. stat	P-value
Ph	Wet season	26	-19.52	0.00*	-71.18	0.00*
	Dry Season	26	-89.52	0.00*	-71.18	0.00*
BD	Wet season	-	-	-	-311.61	0.00*
	Dry Season	-	-	-	-468.5	0.00*
OC	Wet season	-	-	-	-	-
	Dry Season	-	-	-	-	-
TN	Wet season	26	-2401.3	0.00*	-197.63	0.00*
	Dry Season	26	-2497.5	0.00*	-205.17	0.00*
P	Wet season	26	252.75	0.00*	-22.58	0.00*
	Dry Season	26	250.74	0.00*	-24.79	0.00*
Na	Wet season	26	64.49	0.00*	25.38	0.00*
	Dry Season	26	37.62	0.00*	15.78	0.00*
K	Wet season	26	60.03	0.00*	60.03	0.00*
	Dry Season	26	39.29	0.00*	39.29	0.00*
Mg^{2+}	Wet season	26	-56.27	0.00*	-15.36	0.00*
	Dry Season	26	-62.59	0.00*	-16.91	0.00*
C^{2+}	Wet season	26	-318.2	0.00*	-949.7	0.00*
	Dry Season	26	-307.9	0.00*	-918.1	0.00*
Ex.A	Wet season	26	-	-	-	-
	Dry Season	26	-	-	-	-
CEC	Wet season	26	80.21	0.00*	21.49	0.00*
	Dry Season	26	37.73	0.00*	10.89	0.00*
		Heavy Metals				
Zn	Wet season	26	122.82	0.00*	-1.49	0.149
	Dry Season	26	82.64	0.00*	-2.729	0.011*
Cu	Wet season	26	11.55	0.00*	-2.87	0.008*
	Dry Season	26	6.27	0.00*	-2.87	0.008*
Fe	Wet season	26	-109.2	0.00*	-167.9	0.00*
	Dry Season	26	-46.84	0.00*	-17.64	0.00*
Mn	Wet season	26	-	-	-44.22	0.00*
	Dry Season	26	-	-	-33.16	0.00*
Pb	Wet season	26	1.33	0.195	-0.01	0.992
	Dry Season	26	65.96	0.00*	30.44	0.00*

*Significant at 0.05%

The analysis also showed statistical variation with the FAO limit for Cu (0.008<0.05), Fe (0.0<0.05), and Mn (0.0<0.05) across the season, the dry season samples also showed statistical variation for Zn (0.011<0.05) and Pb (0.00<0.05) respectively. The result indicates the study hypothesis three (there is no significant variation in the concentration of physiochemical and heavy metal contents of soil, water (ground and surface) and plant samples to global (WHO/FAO) and national standards (NESREA and NSDWQ), applicable to the conformity of quality and the FAO and NESREA standard is rejected. Thus, it is believed that the various physiochemical and heavy metals content in the sampled soil around the Gousa dumpsite showed significant variation to the established soil quality set by the NESREA and FAO respectively. This implied that the presence of the dumpsite has modified the soil physiochemical quality and the metal load accumulation of the soils in and around the dumpsite. Thus, hypohtesis 3a is rejected. This conclusion is not farfetched from previous findings in Nigeria (Ogbuehi *et al*., 2021). Thus, the study hypothesis three is rejected for soil physiochemical and heavy metals concentration in the study area.

Relationship of Physiochemical and Heavy Metals Concentration in the Sampled Soils

Table 8 presents the correlation of wet season soil physiochemical properties. The result showed that the concentration of pH in the top and subsoil samples are significantly correlated (r = 0.792; 0.001<0.05), likewise, BD showed a significant correlation across the soil horizon (r = 0.741; 0.02<0.05). Similarly, the subsoil samples showed a significant correlation for BD and OC (r = -0.605; 0.022<0.05), C^{2+} and OC (r = 0.5442; 0.044<0.05), Mg^{2+} and CEC (r = 0.583; 0.029<0.05), C^{2+} and Ex.A (0.641; 0.014<0.05). Similarly, the topsoil showed significant positive correlation for OC and Na^{+} (r = 0.538; 0.047<0.05), Mg^{2+} and CEC (r = 0.755; 0.001<0.05), and C^{2+} and CEC (r = 0.745; 0.002<0.01). The concentration P (r = 0.817; 0.000<0.05), Mg^{2+} (r = 0.964; 0.000<0.05), C^{2+} (r = 0.982; 0.000<0.05), and Ex.A (r = 0.806; 0.001<0.05) in the wet season samples for both top and subsoil were also significantly correlated. Thus, applicable to the study hypothesis 1 (there is no significant relationship between the physiochemical and heavy metal content in the soil samples).

The correlation matrix of physiochemical properties of the dry season samples shows a significant relationship in the top and subsoil samples for BD (r = 0.929; 0.000<0.05) TN (r = 0.868; 0.000<0.05), Pa (r = 0.721; 0.004<0.05), K^{+} (r = 0.692; 0.006<0.06), Mg^{2+} (r = 0.969; 0.000<0.05), C^{2+} (r = 0.944; 0.000<) and Ex.A (r = 0.909; 0.000<0.05). Similarly, the topsoil samples showed a significant relationship in the concentration of pH and CEC (-0.562; 0.037<0.05), TN and K^{+} (r = -0.746; 0.002<0.05), C^{2+} and Ex.A (r = 0.616; 0.019<0.05), C^{2+} and CEC (0.582; 0.029<0.05) respectively. In the subsoil samples, the concentration of TN and Pb (r = -0.599; 0.024<0.05), and Mg^{2+} and CEC (r = 0.784; 0.001<0.05) showed a significant relationship as presented in Table 8.

The relationship of individual heavy metals in the sampled soils for both wet and dry seasons showed that the Fe in the top and subsoil samples is negatively correlation (r = -0.605; 0.022<0.05). Similarly, the availability of Cu and Mn in the subsoil's samples are statistically correlated given by the r = 0.625 and p-value of 0.017<0.05. The dry season samples showed a significant correlation in the concentration of Zn (r = 0.814; 0.000<0.05), Cu (r = 0.812; 0.000<0.05), Fe (0.981; 0.000<0.05), Mn (r = 0.989; 0.000<0.05) and P (r = 0.790; 0.001<0.05) in the top and subsoil samples respectively, while the topsoil samples showed a significant positive correlation in the concentration of Zn and Fe (r = 0.580; 0.029<0.05). The relationship of heavy metal pollutants in soils around dumpsite have been established elsewhere in Benin City where the concentration of Cr and other heavy metals (Cd, Ni, Pb, As) as well as Cd and Ni with other metals (Cr, Pb, As and Hg) showed significant relationship (Imasuen and Omorogieva, 2013). Similarly, dumpsites soils showed significant relationship in the concentration of heavy metals (Al, Cr, Cd, Cu, Mn and Pb) in Kuje and Kwali Area Council of the FCT (Ojiego *et al.,* 2022).

Conclusion

The study concluded that the soil physical properties including particle size analysis were products of the parent materials and not affected by the presence of the Gousa dumpsite. The presence of the dump site has resulted in the enrichment of soil chemical properties above the NESREA and FAO limit for healthy soil particularly, Na and CEC and the presence of the Gousa dumpsite is contributing to the soil heavy metal pollution such as Zn, Cu, Fe, Mn and Pb against the NESREA and FAO limit.

Recommendations

Based on the findings and conclusion of the study, the following recommendations are considered appropriate:

1. A contemporary approach to managing and dealing with waste is necessary, which entails implementing policies for proper treatment. Before being disposed or after disposal, there should be regulation of waste disposal through pre-treatment means in the FCT and Nigeria at large.
2. Landfill and waste dump site are attributed to compounding environmental pollution, as such, for an urban city like Abuja, a modern waste management facility aside from dumpsites should be established. This may include incinerators, recycling plants, composting facilities, transfer stations and recovery sites. This is achievable through public-private partnership agreement.

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