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Physico-Chemical Properties and Fertility Status of Dumpsite Soils in Nasarawa State, Nigeria

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Abstract

Dumpsites significantly influence soil quality through continuous deposition of organic and inorganic wastes. This study assessed the ***physico-chemical properties and fertility status*** *of soils from selected dumpsites in Lafia, Keffi, and Karu Local Government Areas of Nasarawa State, Nigeria. Soil samples collected during the rainy season were analyzed for particle size distribution, pH, electrical conductivity (EC), organic carbon (OC), organic matter (OM), total nitrogen (N), available phosphorus (P), exchangeable bases, cation exchange capacity (CEC), and base saturation (BS). Results showed that soil pH ranged from* ***6.4 to 7.3,*** *indicating slightly acidic to neutral conditions. Electrical conductivity varied from* ***122 to 601 µS/cm,*** *reflecting low to moderately high salt concentrations. Organic carbon (2.10–2.47%) and organic matter (3.61–4.25%) were consistently high across all dumpsites, while total nitrogen (0.42–0.56%) and available phosphorus (5.63–6.68 ppm) were within moderate to high ranges. However, exchangeable bases (K, Na, Ca, Mg) were generally low (≈0.01–0.08 cmol/kg), resulting in low cation exchange capacity (0.37–0.64 cmol/kg) and base saturation (5.5–16.2%).Physical properties revealed dominance of sand fractions* ***(80.4–87.4%),*** *with low silt (5.0–6.0%) and moderate clay (7.2–13.2%), classifying the soils as* ***sandy to loamy sand textures.*** *These conditions indicate high permeability and low nutrient retention capacity. The study concludes that although dumpsite soils exhibit improved nutrient status due to organic waste accumulation, their poor structural stability and low nutrient retention limit their agricultural suitability. Sustainable waste management and soil remediation strategies are therefore recommended.*

Keywords: *Dumpsite soil, Soil fertility, Physico-chemical properties, Nasarawa State, Environmental pollution*

INTRODUCTION

Soil is a vital natural resource that supports plant growth, regulates environmental processes, and sustains food production systems. Its productivity is largely controlled by its physico-chemical properties, including texture, structure, organic matter content, and nutrient availability. However, increasing anthropogenic activities have significantly altered soil quality, leading to contamination and degradation in many parts of the world. Soil pollution has been linked to various human activities such as municipal waste disposal, industrial emissions, and agricultural practices, all of which contribute to the accumulation of toxic substances in soils (Misra and Mani, 2009; Fong et al., 2008; Van and Krivolutsky, 1996; Jia et al., 2010) .

In developing countries such as Nigeria, rapid urbanization, population growth, and changing consumption patterns have resulted in a substantial increase in solid waste generation. Due to inadequate waste management systems, open dumping remains the most common method of waste disposal. These dumpsites typically contain heterogeneous materials such as organic waste, plastics, metals, and electronic waste, which decompose over time and release contaminants into the soil environment (Hussain et al., 2016; Umutesi et al., 2018). The indiscriminate disposal of such waste materials leads to the formation of leachate (a complex liquid containing organic

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matter, nutrients, and hazardous substances) which infiltrates the soil and alters its properties (Ekere et al., 2017).

The decomposition of organic waste in dumpsites can enhance soil fertility by increasing organic matter and nutrient availability, particularly nitrogen and phosphorus. However, this apparent improvement in fertility may be misleading, as the same process can result in soil contamination, salinity build-up, and long-term degradation of soil quality. Leachate migration has been identified as a major pathway through which pollutants are transferred from dumpsites into surrounding soils and groundwater systems (Ololade et al., 2019; Micheal et al., 2018).

One of the most critical environmental concerns associated with dumpsites is the accumulation of heavy metals. Heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), copper (Cu), and zinc (Zn) originate from various sources including batteries, plastics, automobile emissions, fertilizers, and electronic waste (Alloway and Ayres, 1999; David et al., 1997; WRI, 2000). These metals are persistent, non-biodegradable, and capable of bioaccumulating in plants and animals, thereby entering the food chain and posing serious health risks (Lu et al., 2009; ATSDR, 2018). Exposure to heavy metals has been associated with a wide range of health problems, including neurological damage, kidney dysfunction, and carcinogenic effects (Simeonov et al., 2010; Sarkar, 2005).

In addition to chemical contamination, the physical properties of soil play a crucial role in determining its response to waste inputs. Soil texture, which is defined by the relative proportions of sand, silt, and clay, influences water movement, nutrient retention, and contaminant mobility. Sandy soils, for instance, are characterized by high permeability and low cation exchange capacity, making them more susceptible to nutrient leaching and pollutant transport. This interaction between soil physical and chemical properties is essential in understanding the fertility status and environmental behavior of dumpsite soils.

Several studies have reported that dumpsite soils often exhibit increased nutrient levels due to organic waste accumulation but may also suffer from contamination and reduced long-term productivity. Heavy metal pollution has been widely linked to waste disposal activities, particularly in areas where waste segregation and environmental regulations are poorly enforced (Esakku et al., 2003; Mahipal et al., 2016) . Furthermore, improper waste management practices have been shown to contribute significantly to soil, water, and air pollution in developing regions, posing serious threats to environmental sustainability and public health (Mavimbela et al., 2019; Yusuf, 2007).

Despite these concerns, there is still limited comprehensive information on how dumpsites affect both the physical and chemical properties of soils in Nasarawa State, Nigeria. This is particularly important given the increasing use of dumpsite soils for agricultural purposes without adequate assessment of their quality and safety.

Therefore, this study was conducted to evaluate the physico-chemical properties and fertility status of soils from selected dumpsites in Lafia, Keffi, and Karu Local Government Areas of Nasarawa State, Nigeria. Specifically, the study aimed to assess soil physical characteristics (particle size distribution and texture), determine key chemical properties (pH, electrical conductivity, organic carbon, total nitrogen, available phosphorus, exchangeable bases, cation exchange capacity, and base saturation), and examine the implications of these properties for soil fertility and sustainable land use.

MATERIALS AND METHODS

Study Area

The study was conducted in selected major dumpsites located in Lafia, Keffi, and Karu Local Government Areas (LGAs) of Nasarawa State, Nigeria (Fig. 1). These locations were selected due to their socio-economic relevance: Lafia serves as the state capital, Keffi is one of the oldest urban centers, and Karu is the most densely populated LGA due to its proximity to the Federal Capital Territory, Abuja (NPC, 2006).

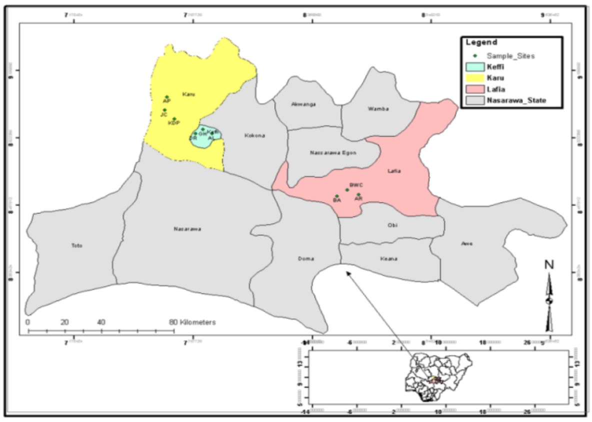

Fig. 1: Map of Nasarawa State showing the study areas

Location of Nasarawa State

Nasarawa State is centrally located in the Middle Belt region of Nigeria. The state lies between latitude 7° 45′ and 9° 25’ N of the equator and between longitude 7° and 9° 37′ E of the Greenwich meridian. It shares boundary with Kaduna state in the North, Plateau State in the East, Taraba and Benue states in the south while Kogi and the Federal Capital Territory flanks it in the West (Fig.2). The state has a total land area of 26,875.59 square kilometers and a population of about 1,826,883, (NPC, 2006).

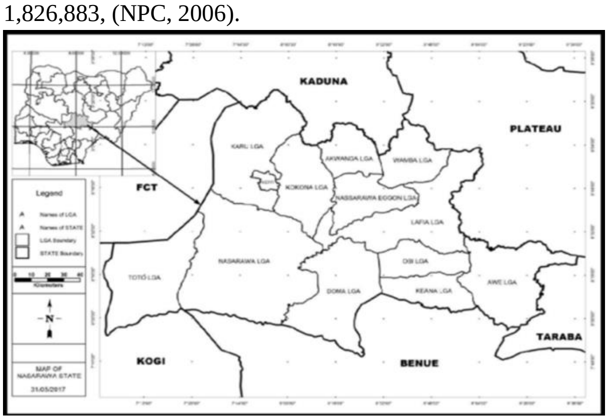

Fig. 2: Map of Nigeria showing Nasarawa State

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Climate, Geology, and Vegetation
The area experiences a tropical wet and dry (savanna) climate, characterized by distinct wet and dry seasons. Mean annual temperature is about 29.39°C**,** with peak temperatures occurring between February and April. Annual rainfall averages 136.71 mm, with about 155 rainy days**,** and relative humidity ranges from 75–90% during the wet season (NIMET, 2025).

Geologically, Nasarawa State comprises Basement Complex rocks, Younger Granites, and sedimentary formations**,** including shales and sandstones. The soils are predominantly highly leached Alfisols**,** characterized **by** strong acidity, low organic matter, and low nitrogen and phosphorus contents (Agbede et al., 2011).

Vegetation is typical of the Southern Guinea Savanna, consisting of grasses, shrubs, and scattered economic trees such as *Vitellaria paradoxa*, *Parkia spp.*, *Gmelina arborea*, *Anacardium spp.*, and *Mangifera indica*.

Study Design and Soil Sampling
The study involved field sampling and laboratory analysis of soils collected from selected dumpsites during both dry (January–March) and rainy (June–October) seasons.

Soil samples were collected from a depth of 0–30 cm using a clean stainless-steel shovel. At each dumpsite, samples were randomly taken from four (spots) and combined to form a composite sample representative of each site.

Sample Preparation
Collected soil samples were prepared following standard procedures:

- Air-drying under shade to reduce moisture content
- Pulverization using mortar and pestle
- Sieving through a 2 mm mesh to remove coarse particles
- Weighing and storage in labeled polythene bags to prevent contamination

Laboratory Analysis of Soil Properties
Routine analysis included determination of both physical and chemical properties of the soil.

Particle Size Distribution
Determined using the Bouyoucos hydrometer method (Day, 1965).

Soil pH
Measured in soil-water and soil-KCl (1:1 ratio) using a glass electrode pH meter (Bates, 1954).

Electrical Conductivity (EC)
Measured to assess soil salinity using standard conductivity procedures.

Organic Carbon and Organic Matter
Organic carbon was determined using the Walkley-Black dichromate oxidation method and converted to organic matter using a factor of 1.72 (Allison, 1965).

Total Nitrogen
Determined using the Macro-Kjeldahl digestion method (Bremner, 1965).

Available Phosphorus
Extracted using Bray-1 solution and determined by the vanado-molybdate colorimetric method (Bray and Kurtz, 1945).

Exchangeable Bases (K, Na, Ca, Mg)
Determined using atomic absorption spectrophotometry, while potassium was measured using a flame photometer.

Cation Exchange Capacity (CEC)
Determined using the ammonium acetate method, expressed in cmol/kg.

Base Saturation
Calculated as:

$$\frac{Summation\ of\ Exchangeable\ bases\ X\ 100}{CEC}$$

Heavy Metal Analysis
Heavy metal concentrations were determined for both seasons. Soil samples (100 g) were digested using 2M HNO_3**,** heated **at** 90–100°C for 3 hours, and filtered. The digest was diluted to 100 ml and analyzed using an Atomic Absorption Spectrophotometer (Perkin Elmer) following standard procedures and manufacturer guidelines.

Data Analysis
All data obtained were subjected to Analysis of Variance (ANOVA) using STATISTIX 10.0 software**,** and treatment means were separated using Least Significant Difference (LSD) at 5% probability level**.**

Results and Discussion

Physical and Chemical properties of soils in some selected dumpsite in the study area

Physical and Chemical properties of Soils in Dumpsites of Lafia LGA
The result of soil fertility status of soils in some selected dumpsites of Lafia LGA in rainy season is presented in (Table 1). The soil of Army secondary school, Angwan Rere and Abdullahi Ibrahim Skills Centre dumpsites were all slightly acidic with pH of 6.8, 6.8 and 6.9 respectively. Total nitrogen and phosphorus were medium to high in all the dumpsites soils in Lafia LGA. The organic carbon and organic matter of all the soil of Army secondary school, Angwan Rere and Abdullahi Ibrahim Skills Centre dumpsites were high. Also, the electrical conductivity of all the soil of Army secondary school, Angwan Rere and Abdullahi Ibrahim Skills Centre dumpsites were moderately high. However, base saturation and the cation exchange (K, Ca, Mg, and Na) were very low in all soil of Army secondary school, Angwan Rere and Abdullahi Ibrahim Skills Centre dumpsites assessed. Furthermore, the sand content in soil of Army secondary school, Angwan Rere and Abdullahi Ibrahim Skills Centre dumpsites was very high in sand particles. The soil texture in soil of Army secondary school, Angwan Rere and Abdullahi Ibrahim Skills Centre dumpsites very sand.

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Table 1: Physical and Chemical Properties of Soils in Dumpsites of Lafia LGA

DUMPSITES LOCATION	pH H_2O	pH kcl	Ec µs/cm	% O.C	% O.M	% N	Avail P(ppm)	K (Cmol/Kg)	Na (Cmol/Kg)	Ca (Cmol/Kg)	Mg (Cmol/Kg)	TEA	CEC	% B.S	% Sand (PARTICLE SIZE)	% Silt (PARTICLE SIZE)	% Clay (PARTICLE SIZE)	Texture
Army Secondary Sch.	7.1	6.8	329	2.38	4.10	0.49	6.25	0.01	0.01	0.021	0.01	0.33	0.39	14.3	85.4	5.4	9.2	Sand
Angwan Rare	7.0	6.8	287	2.38	4.10	0.49	6.02	0.01	0.01	0.01	0.01	0.33	0.38	13.1	87.4	5.4	7.2	Sand
Abdullahi Ibrahim Skills Centre	7.0	6.9	320	2.24	4.02	0.45	6.29	0.01	0.01	0.01	0.01	0.33	0.38	14.0	85.8	5.0	9.2	Sand
LSD(0.05)	0.23	0.40	3.02	0.03	0.13	0.08	0.05	0.01	0.01	0.03	0.01	0.01	0.08	0.13	0.47	0.13	0.26	

Sources: Author's Field Work, 2025

Physical and Chemical properties of Soils in Dumpsites of Keffi LGA

The result of soil fertility status of soils in some selected dumpsites of Keffi LGA in rainy season is presented in (Table 2). The soil of Dauruwa was slightly acidic with pH of 6.4; while soils in General Hospital Keffi and Angwan Lambu were both neutral with pH of 7.1 and 7.2 respectively. Total nitrogen and phosphorus were medium to high in all the dumpsites soils in Keffi LGA. The organic carbon and organic matter of all the soils in Keffi general hospital, Angwan Lambu and Dauruwa dumpsites in Karu LGA were high. Also, the electrical conductivity of soil in Daurawa dumpsite was moderately high; compared to the ones in both General hospital Keffi and Angwan Lambu were low. However, base saturation and the cation exchange (K, Ca, Mg, and Na) were very low in all soils of General hospital keffi, Angwan Lambu and Dauruwa dumpsites assessed. The sand content was very high in soil of General hospital keffi compared to Angwan Lambu and Daurawa dumpsites. The clay content was also moderate in soils of Angwan Lambu and Daurawa dumpsites; while the silt was very low in all the soils studied in Keffi LGA dumpsites. The soil texture of General hospital in keffi dumpsite was known to be sandy; while the soils of Angwan Lambu and Daurawa dumpsites were known to be loamy sand.

Table 2: Soil Fertility Status of Soils in Dumpsites of Keffi LGA

DUMPSITES LOCATION	pH H_2O	pH kcl	Ec µs/cm	% O.C	% O.M	% N	Avail P(ppm)	K (Cmole/Kg)	Na (Cmole/Kg)	Ca (Cmole/Kg)	Mg (Cmole/Kg)	TEA	CEC	% B.S	% Sand (PARTICLE SIZE)	% Silt (PARTICLE SIZE)	% Clay (PARTICLE SIZE)	Texture
Keffi General Hospital	7.1	7.0	122	2.38	4.10	0.49	6.23	0.01	0.02	0.03	0.01	0.33	0.394	16.2	85.4	5.4	9.2	S
Angwan Lambu	7.2	7.0	182	2.45	4.21	0.56	6.56	0.01	0.01	0.03	0.01	0.33	0.39	14.5	83.4	5.4	11.2	LS
Dauruwa	6.9	6.4	403	2.30	3.96	0.42	5.86	0.01	0.01	0.02	0.01	0.50	0.55	8.30	80.8	6.0	13.2	LS
LSD(0.05)	0.26	0.26	0.76	0.76	0.14	0.04	0.04	0.01	0.01	0.03	0.01	0.24	0.02	0.47	0.60	1.29	0.01	

Sources: Author's Field Work, 2025

Physical and Chemical properties of Soils in Dumpsites of Karu LGA

The result of results of physical and chemical properties of soils in some selected dumpsites of Karu LGA in rainy season is presented in (Table 3). The soil of Ado-pandam was slightly acidic with pH of 6.4; while soils in Jeleke close and Kadefe were both neutral with pH of 7.0 and 7.3 respectively. Total nitrogen and phosphorus were medium to high in the soil of Ado-pandam, Jeleke close and Kadefe dumpsites. The organic carbon and organic matter of all the soils in the dumpsites in Karu LGA were high. Also, the electrical conductivity of soil in Jeleke close close dumpsite was moderately high; but the ones in both Ado-pandam and Kadefe were low. However, base saturation and the cation exchange (K, Ca, Mg, and Na) were very low in all soils assessed. The sand content was high and the clay content was also moderate; while the silt was very low in all the soils studied in Karu LGA dumpsites. Therefore, the soil texture of all the soils assessed was known as loamy sand.

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Table 3: Physical and Chemical Properties of Soils in Dumpsites of Karu LGA

DUMPSITES LOCATION	pH H_2O	pH kcl	Ec µs/cm	% O.C	% O.M	% N	Avail P(ppm)	K (Cmole/Kg)	Na (Cmole/Kg)	Ca (Cmole/Kg)	Mg (Cmole/Kg)	TEA	CEC	% B.S	% Sand	% Silt	% Clay	Texture
Ado – Pandom	6.5	6.4	246.00	2.10	3.61	0.42	5.63	0.01	0.08	0.02	0.01	0.50	0.64	5.5	83.4	5.4	11.2	LS
Jelenke close Maraba	7.0	6.8	601.00	2.35	4.04	0.49	6.01	0.01	0.01	0.02	0.01	0.33	0.37	9.6	80.8	6.0	13.2	LS
Kadefe Maraba	7.3	7.2	322.00	2.47	4.25	0.56	6.68	0.01	0.02	0.01	0.01	0.33	0.38	13.2	80.4	5.4	13.2	LS
LSD(0.05)	0.35	0.47	1.31	0.11	0.01	0.01	0.39	0.01	0.14	0.01	0.01	0.24	0.04	0.35	0.01	1.42	0.01	

Sources: Author's Field Work, 2025

General Discussion across the Study Area

The soils across the studied dumpsites in Lafia, Keffi, and Karu LGAs showed a relatively similar fertility pattern, characterized by both beneficial and adverse properties. The soils generally contained high organic carbon and organic matter contents, moderate to high levels of nitrogen and available phosphorus, and slightly acidic to neutral pH conditions, which are generally favorable for crop growth. These findings indicate that the continuous deposition and decomposition of municipal wastes contributed substantial organic residues and nutrients to the soils. Similar observations have been reported by Alloway (1996) and Amadi et al. (2010), who noted that decomposed organic wastes can temporarily improve soil fertility through nutrient enrichment. The improved fertility status may therefore be linked to the decomposition of food residues, plant materials, paper, and other biodegradable wastes that release essential nutrients such as nitrogen, phosphorus, and potassium into the soil. In some cases, ash and alkaline waste materials may also contribute to slight increases in soil pH, thereby improving nutrient availability.

Despite these apparent fertility benefits, several unfavorable soil characteristics were also observed. Exchangeable bases such as potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) were generally low, while cation exchange capacity (CEC) and base saturation remained poor across most of the dumpsites. These conditions indicate low nutrient retention capacity and reduced long-term soil productivity. Furthermore, the soils were predominantly sandy to loamy sand in texture, suggesting high susceptibility to nutrient leaching, especially during the rainy season. Elevated electrical conductivity (EC) values recorded in some locations also suggest the beginning of salinity build-up, which may adversely affect plant growth if waste accumulation continues unchecked. Similar findings were reported by Oyelola et al. (2009), who observed that dumpsite soils often exhibit temporary nutrient enrichment but poor structural stability and increased contamination risks over time.

Conclusion

This study assessed the physico-chemical properties and fertility status of soils from selected dumpsites in Lafia, Keffi, and Karu Local Government Areas of Nasarawa State, Nigeria. The findings revealed that the soils were generally slightly acidic to neutral in reaction, with relatively high organic carbon, organic matter, total nitrogen, and available phosphorus contents across most of the dumpsites. These conditions indicate that continuous accumulation and decomposition of municipal wastes contributed to temporary improvement in soil nutrient status.

However, despite the apparent nutrient enrichment, the soils were predominantly sandy to loamy sand in texture, with low cation exchange capacity, low base saturation, and poor exchangeable base contents. These characteristics suggest weak nutrient retention capacity, high susceptibility to nutrient leaching, and reduced long-term soil productivity. Elevated electrical conductivity observed in some locations also indicates the possibility of gradual salt accumulation in the soils.

Generally, the study demonstrates that while dumpsite soils may provide short-term fertility benefits due to organic waste deposition, their poor physical structure and limited nutrient holding capacity reduce their suitability for sustainable agricultural use. Proper waste management practices, controlled waste disposal, and appropriate soil improvement measures are therefore necessary to maintain soil quality and support sustainable land use in the study area.

Recommendations

1. Government and environmental agencies should promote proper and regulated waste disposal practices to reduce indiscriminate dumping and minimize soil degradation around dumpsites.
2. Organic waste materials should be properly sorted, composted, and managed before disposal in order to improve their usefulness as soil amendments and reduce environmental pollution.
3. Farmers using soils around dumpsites for agricultural activities should adopt soil improvement practices such as the application of organic manure, cover cropping, mulching, and soil

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conservation measures to improve soil structure and nutrient retention.

4. Regular monitoring of soil physico-chemical properties should be carried out to evaluate changes in soil fertility status and ensure sustainable land management.
5. Public awareness campaigns should be intensified to educate communities on the environmental effects of improper waste disposal and the importance of sustainable waste management practices.
6. Further studies should be conducted to assess seasonal variations in soil fertility parameters and the long-term impacts of waste accumulation on agricultural productivity and environmental quality.

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