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Research Article

Geoengineering and Environmental Risk Assessment of The Near-Surface Geology at An Abandoned Dumpsite: A Case Study from Oluku, Ovia North-East, Southern Nigeria

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Abstract

This research presents an integrated environmental and geotechnical assessment of the abandoned Oluku dumpsite in Benin City, Southern Nigeria. The investigation examined soil physicochemical properties, heavy metal concentrations, plant (Musa paradisiaca) metal uptake, groundwater quality, and geotechnical behavior, supported by risk indices and statistical analyses. Soil parameters included pH, electrical conductivity (EC), total dissolved solids (TDS), organic matter (OM), organic carbon (OC), nitrate, nitrite, phosphorus, sulphur, and particle size distribution. Heavy metals including Pb, Cd, Cr, Ni, Cu, Zn, Mn and Fewere quantified in soils, plantain leaves, and groundwater. Ecological and human-health risks were assessed using contamination factor (CF), geo-accumulation index (Igeo), enrichment factor (EF), potential ecological risk index (PERI), and transfer factor (TF). Regression analyses and a comparative temporal analysis with 2020 data were also performed. Water samples from boreholes around the dumpsite's vicinity were assessed for physicochemical, and microbial parameters. Geotechnical parameters included Plasticity, compaction behavior, and shear strength. All measured parameters were evaluated against relevant national and international standards.

The soils were predominantly loamy sand with low organic matter (2.50–5.76%) but from an engineering perspective, they exhibited clayey behavior with near-neutral pH (6.0–7.84) i.e., soils had high plasticity with presence of organic matter, conditions that can favor metal mobility and also affect engineering performance. Pbconcentrations in soils exceeded NESREA permissible limits at several sampling points, with risk indices classifying Pb contamination as significant and strongly anthropogenic in origin. Temporal comparison of soil data between 2020 and 2024 showed decreases in Cd, Ni, Cu, Zn, Mn, and Fe, indicating partial natural attenuation. However, Pb and Cr remained consistently high, suggesting persistent contamination sources. In plantain (Musa paradisiaca) leaves, Pb, Cd, Ni, Cr, Mn, and Cu were aboveFAO/WHO limits, indicating potential food-chain exposure. While Zn and Fe were within safe ranges,their marginal concentrations suggested micronutrient deficiencies. Regression analysis further revealed that Pb, Cr, and Cd jointly inhibited Fe uptake in leaves, explaining the observed chlorosis. Groundwater was acidic, poorly buffered, and variably impacted by leachate, with Pb, Fe, and Cr exceeding safe thresholds. Microbial assessment showed only low counts of heterotrophic bacteria, and no coliforms, E. coli, Staphylococcus aureus, or fungi, indicating that microbial quality met WHO and NSDWQ standards. Engineering investigations indicated particle size are fine-grained with presence of organic content having high compaction potential, with maximum dry densities of 1.46-1.57 g/cm3 at optimum moisture contents of 16.8-25.3%, and triaxial compression tests showing cohesion values between 30 to 36KN/m3 and corresponding friction angles 13.2-14.6˚. Based on these findings, the Oluku dumpsite poses significant environmental and engineering risks, and will require targeted remediation strategies such as land-use restrictions, phytoremediation, soil amendments, engineered capping, and continuous monitoring prior to any agricultural or structural development.

Keywords: Dumpsite contamination, Heavy metals, Soil-plant transfer, Groundwater quality, geotechnical behavior, Environmental risk assessment, Dumpsite reclamation.

Introduction

Rapid population growth has increased the demand for housing, yet land for construction remains scarce and often unavailable [1]. This has led to the reclamation of abandoned dumpsites and other marginal lands, raising concerns about geotechnical stability and environmental safety. Solid waste mismanagement continues to be a prevalent issue in many developing countries, where open dumpsites serve as the primary disposal method. Unlike engineered landfills, dumpsites lack proper lining, leachate collection, and cover systems, allowing uncontrolled release of contaminants into surrounding soils, groundwater, and vegetation [2-4]. Over time, these sites accumulate heavy metals that are non-biodegradable, persistent, and capable of entering the food chain through soil–plant transfer pathways.

Among these metals, lead (Pb), cadmium (Cd), and chromium (Cr) are particularly concerning due to their toxicity, persistence, and bioaccumulative potential [5,6]. In soils, heavy metals reduce bearing strength, increase porosity, and impair durability, leading to uneven settlement. They also disrupt microbial activity, reduce fertility, and impair nutrient cycling. In plants, heavy metals interfere with physiological and biochemical processes, reducing yields and causing visible damage such as chlorosis [3]. The mobility and bioavailability of metals depend strongly on soil characteristics such as texture, pH, organic matter, and nutrient levels. Sandy soils with low clay and organic matter have poor metal retention, while acidic pH enhances solubility of metals such as Pb and Cd, increasing plant uptake [2]. Once translocated into edible tissues, these metals pose direct risks to food security and human health. Risk indices including transfer factor (TF), contamination factor (CF), enrichment factor (EF), geoaccumulation index (Igeo), and potential ecological risk index (PERI) are commonly used to quantify these hazards [7,8].

Groundwater beneath and surrounding abandoned dumpsites are particularly vulnerable to contamination from leachate, which can elevate metal concentrations and alter physicochemical properties such as pH, electrical conductivity, total dissolved solids, and hardness. Microbial contamination may also occur, posing additional health risks if wells are used for drinking water.

From a geotechnical perspective, soils at reclaimed dumpsites often exhibit heterogeneous properties, including high plasticity, compressibility, and variable shear strength, which may compromise load-bearing capacity and foundation stability. Such conditions complicate engineering applications, particularly for housing construction or infrastructure development.

Despite these risks, few studies have simultaneously evaluated the combined environmental and geotechnical hazards of abandoned dumpsites. In Nigeria, abandoned sites are widespread but largely unmonitored, leaving uncertainties regarding long-term ecological and health impacts. The Oluku dumpsite in Benin City exemplifies this gap: although baseline heavy metal data exist, no follow-up studies have examined temporal changes, plant uptake, groundwater contamination, or geotechnical stability.

This study therefore aims to assess the current status and ecological risks of heavy metal contamination in soils, examine metal uptake in plantain leaves, evaluate groundwater quality, and determine geotechnical properties of the Oluku dumpsite. By comparing current findings with temporal trends, the study provides guidance for environmental remediation and safe land reclamation strategies, particularly for engineering applications.

Materials And Methods

Study Area

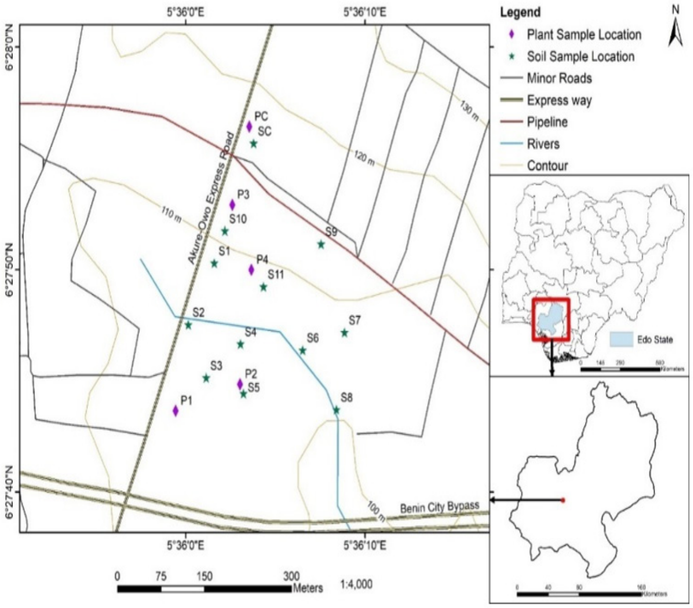

Figure 1: Location Map of Study Area

The study was conducted at the abandoned Oluku dumpsite, located in Ovia North-East Local Government Area of Benin City, Edo State, Nigeria (Figure 1). Geographically, the site lies between latitudes 6º 27’ 43” and 6º 27’ 58” N and longitudes 5º 35’ 59” and 5º 36’ 10” E, at an elevation of approximately 120 m above sea level. The area experiences a humid tropical climate, with a mean annual rainfall of about 2,000 mm and an average temperature of 27 °C. Rainfall is strongly seasonal, with a wet season from April to October and a dry season from November to March.

The regional geology is dominated by the Benin Formation, comprising primarily coarse sands, gravel, and minor clay lenses. These sandy materials are highly permeable and poorly consolidated, facilitating infiltration and mobility of contaminants [9]. Land use surrounding the dumpsite is mixed, including residential settlements, farmlands, and small-scale commercial activities. Plantain (Musa paradisiaca) is commonly cultivated in the area and was selected as the representative species for vegetation analysis due to its dietary importance and known capacity to accumulate heavy metals.

Waste disposal at the Oluku dumpsite ceased in the early 2020s following government intervention; however, no remediation measures were implemented. Consequently, the site remains largely unmanaged, with visible waste residues, leachate discharge, and sporadic vegetation cover. Its abandoned status makes it an ideal location for assessing the persistence of contamination, the mobility of heavy metals in soil and groundwater, and the potential for natural attenuation over time.

Sampling Method

A total of 24 soil samples (S1–S11), 5 plantain leaf samples (P1–P5), and 3 borehole samples (10 m deep) for geotechnical testing were collected in March 2024. Soil samples were obtained from two depths, 0–15 cm and 15–30 cm, to capture both surface and subsurface contamination. Plantain leaves were collected from mature plants growing directly within the dumpsite. Sampling points were systematically distributed across the site to capture spatial variability, while control samples (SC and PC) were collected at the periphery. All samples were placed in clean polyethylene bags, labeled, and transported to the laboratory for analysis.

Water samples were collected from wells surrounding the dumpsite following [10, 11] guidelines. Physicochemical and heavy metal analyses used 1-L HDPE bottles, while 250 mL sterile glass bottles were used for microbiological analyses.

Laboratory Analysis

Particle Size Distribution (PSD): Soil texture was determined using the hydrometer method [12], and classified according to the USDA soil textural triangle.

Consistency Limits: Atterberg limit defines the moisture content ranges within which soil changes from one state to another from solid to semi-solid, plastic, and liquid states. Two tests were conducted following BS 1377 (Part 2, 1990).

- Liquid Limit (LL): Determined using the Casagrande apparatus. A soil paste was placed in a brass cup, and a groove was cut through it. The cup was repeatedly dropped from a height of 10 mm until the groove closed over a length of 13 mm. The corresponding moisture content was recorded, and the liquid limit was determined as the moisture content at 25 blows.
- Plastic Limit (PL): Determined by rolling the soil into threads until they crumbled at a diameter of 3 mm.
- The Plasticity Index (PI) was calculated as:$PI = LL - PL$

Compaction Test: These tests were performed using the Standard Proctor method (BS 1377, Part 4, 1990) to determine the relationship between dry density and moisture content. Soils were compacted in three layers, each receiving 25 blows from a 2.5 kg rammer dropped from 300 mm. Maximum dry density (MDD) and optimum moisture content (OMC) were determined from the dry density–moisture content curve.

Soil Physico-Chemical Properties: pH, electrical conductivity (EC), and total dissolved solids (TDS) measured using portable meters. Organic carbon (OC) was determined via the Walkley-Black method, and organic matter (OM) was calculated from OC. Nitrate, nitrite, phosphorus, and sulfur were determined following standard protocols.

Heavy Metal Analysis: Soil and plant samples were digested using a mixture of HNO and $HClO_4$ (3:1). Concentrations of Pb, Cd, Cr, Ni, Cu, Zn, Mn, and Fe were quantified using Atomic Absorption Spectrophotometry (AAS).Groundwater metal concentrations were also analyzed similarly.

Data Analysis

Descriptive Statistics: Mean, minimum, maximum, and standard deviation were calculated for soil and plant parameters to assess variability.

Risk Indices: Contamination Factor, Geo-accumulation Index, Enrichment Factor, and Potential Ecological Risk Index were calculated using established formulas.

Transfer Factor (TF): Calculated as the ratio of metal concentration in plant tissues to that in soil, indicating the efficiency of metal uptake and translocation.

Regression Analysis: Regression analysis (Coefficient of determination, regression coefficients and p-values) were used to assess the relationship between parameters. Multiple linear regression was also performed to examine the influence of Pb, Cd, and Cr on Fe concentrations in plantain leaves.

Temporal Comparison: Historical data from Iyebor et al. (2020) were compared with current measurements. Welch's t-test was employed to test for significant differences at $p < 0.05$, accounting for unequal variances.

Results

Soil Characteristics

Soils at the Oluku dumpsite are predominantly sandy with low silt and negligible clay for most sampling points (Table 1). Soil pH was generally slightly acidic to near-neutral. EC and TDS were low, indicating limited soluble salt content. OC and OM levels were minimal. Nitrate, nitrite, phosphorus, and sulfur were all low to moderate (Table 2).

PARAMETER	SAND (%)	SILT (%)	CLAY (%)
Mean±SD	77.08 ± 7.06	21.46 ± 4.88	1.50 ± 3.87
Coefficient of Variance (%)	9.16	22.75	257.82

Table 1: Descriptive statistics of PSD

Physico-chemical Properties	Mean ± SD	Standards
pH	7.10±0.50	5.5 - 7.5
Electrical Conductivity (µS/cm)	52.33±21.84	< 4000
Total Dissolved Solids (mg/kg)	26.43±11.23	500 – 2000
Organic Carbon Content (%)	2.35±0.55	0.6 - 2.5
Organic Matter Content (%)	4.05±0.95	1.5 – 5
Nitrate (mg/kg)	1.73±0.40	10 – 30
Phosphorus (mg/kg)	5.67±1.73	15 – 40
Sulphur (mg/kg)	1.24±0.43	10 – 20
Nitrite (mg/kg)	0.12±1.04	<1

Table 2: Descriptive statistics of soil physicochemical properties

Soil Heavy Metal Concentrations and Contamination Indices

Pb (up to 517.48 mg/kg) and Cd (up to 3.60 mg/kg) significantly exceeding NESREA limits at few isolated sampling points (Table 3). Risk indices classified Pb as heavily contaminated and to be of anthropogenic origin. PERI indicated low overall risk.

Heavy Metal	Zn	Pb	Cd	Ni	Mn	Fe	Cu	Cr
Mean ± SD	13.8±7.5	79.1±118.1	0.8±0.9	0.2±0.1	3.1±1.4	94.9±32.4	2.5±1.7	8.2±5.1
Standards (NESREA, 2011)	10-420	2-164	0.1-3	10-70	-	-	2-100	5-100

Table 3: Descriptive statistics of Soil Heavy Metal Concentrations

Metal	CF	Interpretation	Igeo	Interpretation	EF	Interpretation	Er	Risk Level
Zn	0.6	Low	-1.2	Uncontaminated	1.5	Minor enrichment, mixed origin	0.6	Low
Pb	**13.1**	**Very high**	**3.1**	**Heavily contaminated**	**13.9**	**Significant enrichment, anthropogenic**	**65.4**	**Moderate**
Cd	0.9	Low	-0.8	Uncontaminated	0.9	No enrichment, natural source	26.7	Low
Ni	0.03	Low	-5.7	Uncontaminated	0.2	No enrichment, natural source	0.2	Low
Mn	0.03	Low	-5.6	Uncontaminated	0.03	No enrichment, natural source	0.03	Low
Fe	1.0	Low	-0.7	Uncontaminated	-	Reference element	1.0	Low
Cu	0.4	Low	-2.0	Uncontaminated	0.4	No enrichment, natural source	2.0	Low
Cr	0.8	Low	-0.9	Uncontaminated	0.9	No enrichment, natural source	1.6	Low
Total PERI	-	-	-		-		97.4	Low Risk

Table 4: Combined Risk Indices of Heavy metals in Soil samples

Heavy Metals in Plantain Leaves (uptake and transfer factors)

Pb, Cd, Ni, Mn, Cr and Cu concentrations exceeded FAO/WHO limits, indicating potential food-chain risk. Zn and Fe concentrations were within permissible rangesbut at marginally adequatelevels, raising concerns about potential micronutrient imbalances (Table 5). Cr showed TF > 1(Figure 2), indicating enhanced translocation to leaves under existing soil conditions.

Heavy Metal	Zn	Pb	Cd	Ni	Mn	Fe	Cu	Cr
Mean ± SD	2.0±1.0	9.3±13.1	0.1±0.1	0.2±0.1	2.8±2.8	5.16±1.86	1.7±1.3	8.4±3.2
Standards (FAO/WHO, 2007)	5	0.3	0.2	0.1	0.2	48	1	0.05

Table 5: Descriptive statistics of plant samples

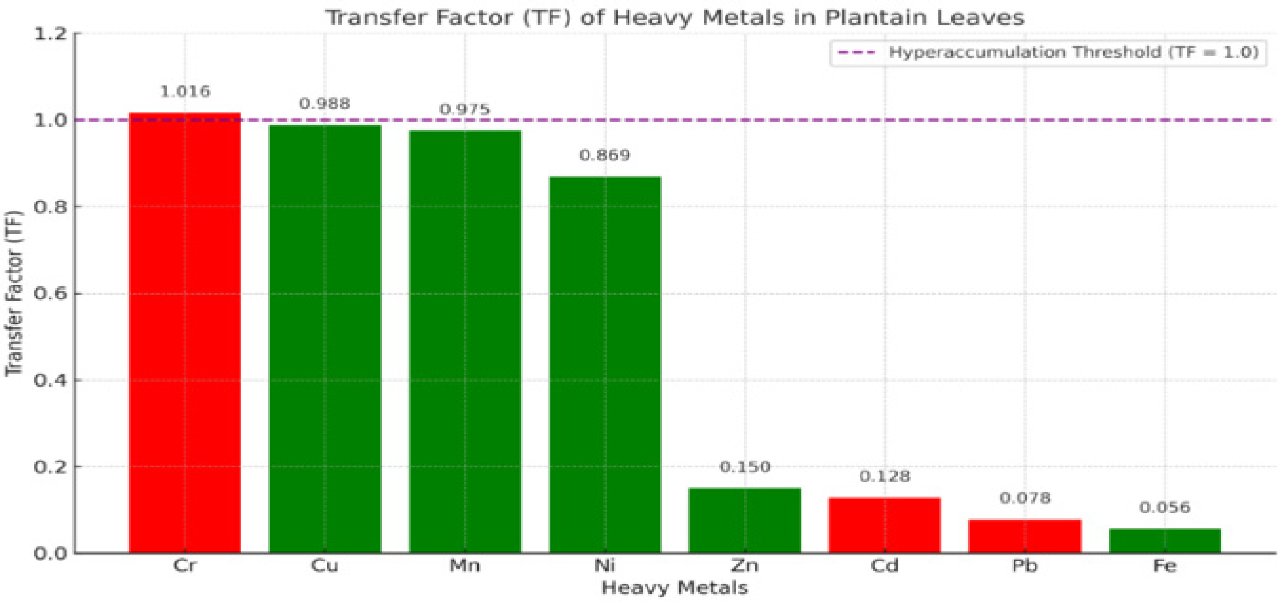

Figure 2: Bar chart of transfer factor

Regression Analysis

A multiple regression model showed that Pb, Cd, and Cr collectively explained over 95% of Fe concentration variability in plantain leaves, with all coefficients negative (Table 6). This indicates antagonism and suppressed Fe uptake, consistent with observed chlorosis.

Model	Regression Equation	R2	Adjusted R2	p-value
Multiple regression (Pb, Cr, Cd)	Fe_leaf = 10.989 - 0.152Pb - 0.080Cr - 0.306Cd	0.954	0.908	< 0.05

Table 6: Multiple regression result for Fe uptake suppression

Temporal Comparison (2020 vs. 2024)

Compared with 2020 data [13], Cd, Ni, Cu, Zn, Mn, and Fe concentrations in soils significantly reduced, indicating partial attenuation (Table 7). However, Pb and Cr increased slightly but not significantly, suggesting persistent contamination.

Heavy Metal	2024 Dataset (Mean ± SD)	2020 Dataset (Mean ± SD)	Trend	Welch’s t-test (p-value)
Lead (Pb)	79.11±118.09	34.86±16.7	Increased	0.2252
Cadmium (Cd)	0.80±0.94	7.02±2.03	Decreased	< 0.0001

Chromium (Cr)	8.15±5.13	6.23±8.46	Slightlyincreased	0.558
Nickel (Ni)	0.19± 0.05	19.84±12.47	Decreased	0.0015
Iron (Fe)	94.95±32.41	8580.56±6923.89	Decreased	0.0062
Copper (Cu)	2.53± 1.69	7.04±2.83	Decreased	0.0011
Zinc (Zn)	13.78±7.53	208.42±169.19	Decreased	0.0087
Manganese (Mn)	3.08±1.43	204.87±	Decreased	< 0.0001

Table 7: Comparative analysis of soil heavy metal concentrations

Groundwater Characteristics

Physicochemical analysis revealed that groundwater is acidic, poorly buffered, and variably impacted by waste leachate (Table 8).Heavy metal concentrations confirmed significant groundwater contamination, with Pb, Fe, and Cr exceeding safe thresholds (Table 9).Microbial results indicated very low bacterial counts, with only total heterotrophic bacteria detected in samples 1, 4, and 5 (Table 10).

Parameter	Units	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	WHO/NSDWQ Limit
pH	–	5.19	6.14	5.88	5.27	5.21	6.5–8.5
EC	µS/cm	35	400	70	22	22	1000
TDS	mg/L	17	201	36	11	11	500
Alkalinity	mg/L	5	4	6	4	6	100–200
Turbidity	NTU	1	0	0	0	1	5
Nitrate	mg/L	0.83	0.52	0.69	0.59	0.68	50
Hardness	mg/L	6	5	4	5	7	150
Phosphate	mg/L	0.49	0.34	0.42	0.37	0.43	5
Sulphate	mg/L	2	1	2	1	2	100
Mg	mg/L	2.29	3.80	0.49	0.28	1.53	0.2
Na	mg/L	4.33	8.96	4.92	3.14	3.05	200
Ca	mg/L	8.20	7.50	8.27	8.53	5.23	75
K	mg/L	0.89	55.80	5.25	1.28	0.87	12

Table 8: Physicochemical analysis of groundwater samples

Sample	Pb (mg/L)	Zn (mg/L)	Fe (mg/L)	Cr (mg/L)
1	0.427	0.35	7.10	3.87
2	0.241	0.32	7.51	2.86
3	0.163	0.26	5.72	0.88
4	0.428	0.28	2.98	0.56
5	0.106	0.36	3.55	0.37
WHO	0.01	3.00	0.30	0.05
NSDWQ	0.01	3.00	0.30	0.05

Table 9: Heavy metalanalysis of groundwater samples

Sample	Units (CFU/mL)	Total Bacteria Count (NA)	Total Coliform Count (MA)	Total E. coli Count (EMB)	Total Staph Count (MSA)	Total Fungi Count (PDA)
1	CFU/mL	1	0	0	0	0
2	CFU/mL	0	0	0	0	0

3	CFU/mL	0	0	0	0	0
4	CFU/mL	1	0	0	0	0
5	CFU/mL	1	0	0	0	0

Table 10: Microbial analysis of groundwater samples

Geotechnical characteristics

The compaction test showed the soils are cohesive having maximum Dry density (MDD) as 1.28g/cm3, 1.57 g/cm3 and 146 g/cm3 to Optimum moisture content (OMC) as 21.5%, 16.8% and 25.3% respectively (Table 11). This is based on [14] OMC/MDD as 20-30/1.44-1.68 g/cm3 for cohesive soils (Fig 3&4).

Samples	**Compaction**		**Consistency Limit**		
	MDD (g/cm3)	**OMC (%)**	**LL**	**PL**	**PI**
BH1	1.48	21.5	56.30	35.32	20.98
BH2	1.57	16.8	51.05	38.99	12.06
BH3	1.46	25.3	56.30	35.32	20.98

Table 11: Summary of Geotechnical Test

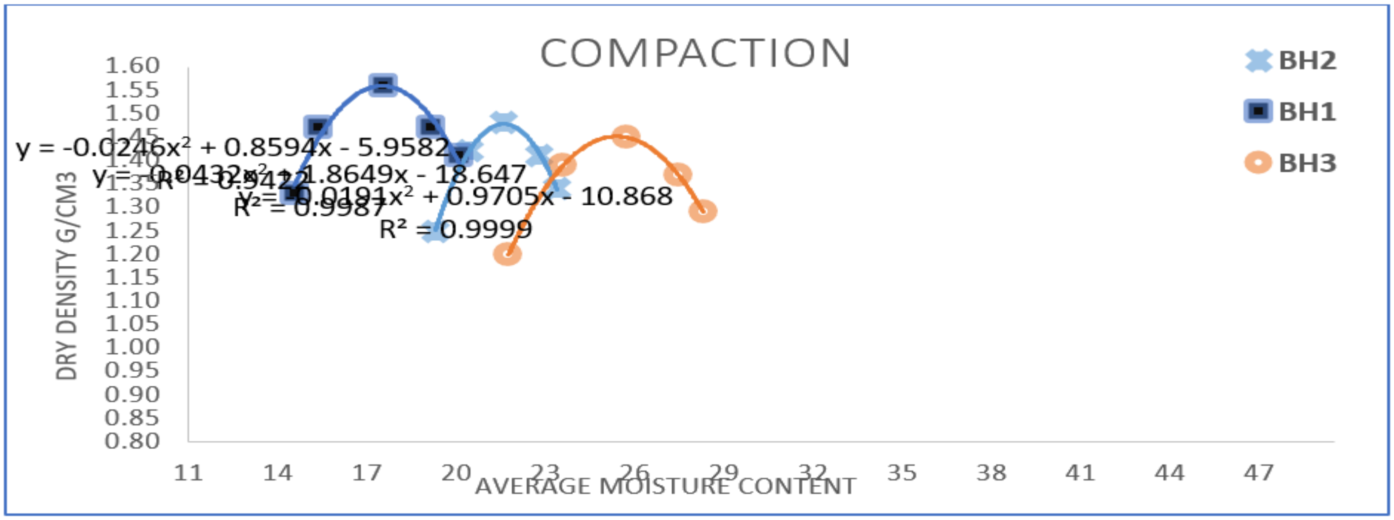

Figure 3: Compaction result of soils from the dumpsite

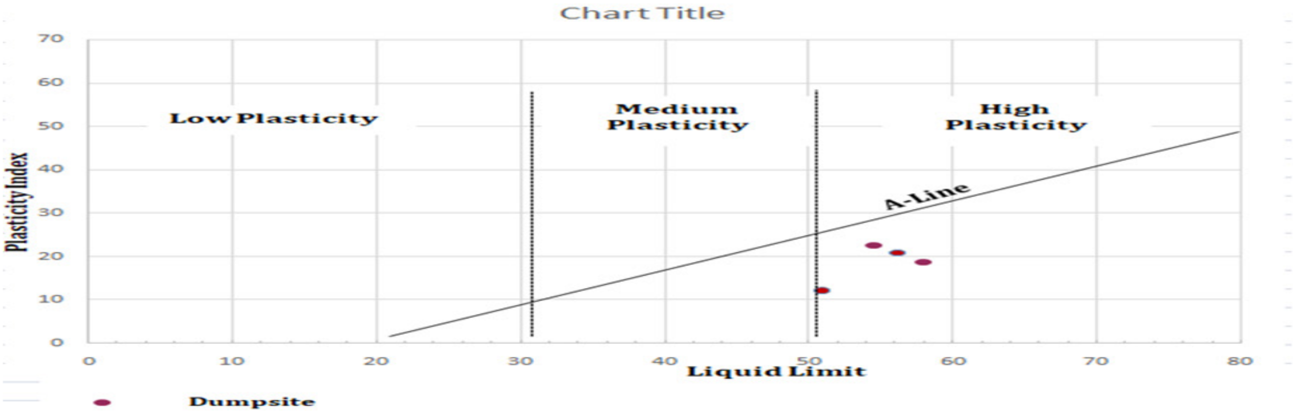

Figure 4: Plasticity chart of soils from dumpsite

The plasticity chart showed that the soils from the dumpsite are high plastic and below the Aline which indicates that the soils are organic clay soils.

Discussion

Soil Characteristics and Metal Mobility

The dominance of sandy fractions at the Oluku dumpsite strongly influences the geochemical behavior of heavy metals. Sandy soils arecharacterized by low cation exchange capacity, minimal organic matter, and weak aggregation, all of which reduce their capacity to adsorb and immobilize metals [15,3,2]. Consequently, contaminants such as Pb, Cd, and Cr remain relatively mobile in the soil solution and available for plant uptake. The slightly acidic to near-neutral pH observed in the samples further enhances solubility of divalent cations, especially Cd^{2+} and Pb^{2+}, which are more mobile under acidic conditions. Previous studies in Nigerian waste sites [16,17] similarly reported that sandy soils with low organic content facilitate heavy metal leaching and plant uptake.

The low organic carbon and organic matter contents observed in the soils suggest limited potential for natural immobilization of metals through complexation with humic substances. Since organic matter acts as both a sink and a buffer for metals [15], its deficiency in these soils implies reduced attenuation capacity. Thus, the soil physicochemical properties at the Oluku dumpsite create conditions where toxic metals remain bioavailable, and this aligns with existing reports that emphasize the pivotal role of soil texture and OM in governing bioavailability of heavy metals in tropical soils [18].

Soil Heavy Metal Concentrations and Ecological Risk Implications

While Zn, Cu, Mn, Fe, Ni, and Cr remained largely within NESREA limits, Pb and Cd exceeded permissible values and represent the main ecological hazards. Pb showed the highest contamination and risk index values, consistent with its environmental persistence and toxicity [19,8]. Cadmium also showed localized elevations, indicating pockets of increased bioavailability. These findings highlight Pb as the dominant contaminant requiring targeted remediation, with other metals presenting low to moderate risks attributable mainly to geogenic inputs.

Heavy Metals in Plantain Leaves and Transfer Factors

Plantain leaves accumulated Pb, Cr, Mn, Cu, Ni, and Cd above FAO/WHO limits, confirming active soil-to-plant transfer and potential food-chain exposure. Although Fe and Zn were within safe limits, their marginal levels suggest nutrient imbalance and metal-induced stress. Transfer factors indicated metal-specific uptake, with Cr, Cu, and Mn being most mobile, while Pb and Fe showed limited translocation. The uptake pattern (Cr > Cu > Mn > Ni > Zn > Cd > Pb > Fe) confirms that Musa paradisiaca is not a general hyperaccumulator but responds selectively to metal availability.These findings identify that the toxic metals at the Oluku dumpsite are not only present in the soil matrix but are also bioavailable and actively taken up by plants, compromising food safety, plant vitality, and ecological resilience [20], and also highlight the importance of assessing metal-specific uptake patterns when choosing the remediation methods suitable to safeguard both plant health and food safety in and around the Oluku dumpsite.

Regression Analysis: Influence on Fe Uptake

The regression model showed that Pb, Cd, and Cr together explained more than 95% of the variation in Fe concentration in plantain leaves, with all three exhibiting significant negative coefficients. This indicates strong antagonistic interactions, where increasing concentrations of these metals suppress Fe uptake and transport. The outcome is consistent with chlorosis symptoms observed in the field, where Fe deficiency manifested as interveinal yellowing.

Similar inhibitory effects have been reported in maize and spinach exposed to Pb and Cd [21,22], suggesting that competitive inhibition at root uptake sites and disruption of Fe metabolism are likely mechanisms. This model provides a solid scientific basis for linking toxic metal contamination with physiological stress in vegetation.

Temporal Comparison of 2020 and 2024 Data

Comparative analysis revealed declines in Zn, Cu, Ni, Cd, Mn, and Fe, suggesting partial natural attenuation through leaching or plant uptake. However, Pb and Cr increased, implying continued release from buried waste or informal dumping. These trends demonstrate limited natural recovery and align with reported persistence of Pb- and Cd-rich fractions in abandoned dumpsites [23,24]. Active remediation is therefore required to reduce long-term risk.

Groundwater Quality and Contamination Pathways

Groundwater was acidic and poorly buffered, conditions that enhance metal mobility. Concentrations of Pb, Cr, and Fe exceeded WHO/NSDWQ limits, confirming leachate infiltration through the highly permeable Benin Formation sands. Although microbiological indicators were absent, chemical contamination rather than microbial pollution poses the primary risk. Local variations in EC, TDS, and potassium further support plume heterogeneity. Overall, groundwater in the area is unsuitable for consumption, and mitigation and monitoring are urgently required.

Geotechnical Analysis

The geotechnical test revealed that the clay content negligible but are highly plastic and organic in nature which is typical in a dumpsite. The compaction test showed the OMC/MDD ratio are cohesive and [14] indicated that its most suitable for engineering purposes hence a good shear strength but with presence of organic content, this shear strength reduces and automatically reducing cohesion and frictional angle, high water content leading to poor compaction as well as increase in plasticity in the dumpsite.

Conclusion

This study provides an integrated environmental and geotechnical assessment of the Oluku dumpsite and shows that the site remains a significant contamination hotspot with poor engineering stability. Sandy and organic soils promoting heavy metal mobility, which resulted in elevated Pb and Cd in soils, toxic metal accumulationof Pb, Cd, Cr, Ni, Mn, and Cu above FAO/WHO limits in plantain (Musa paradisiaca) leaves, and Fe-deficiency chlorosis driven by Pb-Cd-Cr antagonism. Groundwater is acidic and contaminated with Pb, Cr, and Fe above WHO/NSDWQ limits, reflecting leachate infiltration through the permeable Benin formation. Although some metals declined compared to 2020, Pb and Cr persist, indicating ongoing release from buried waste. Geotechnically, subsurface soils behave as high-plasticity organic clays with low shear strength, high compressibility, and settlement susceptibility.

Overall, the dumpsite poses substantial ecological, public health, and engineering risks, making unregulated land reuse unsafe. These findings emphasize the need for controlled land use, routine water-quality surveillance, and engineered soil improvement before any redevelopment. Persistent Pb and Cr contamination indicates that the site cannot self-remediate without intervention. Reinforcing the importance of active remediation strategies is necessary to reclaim the land for future use. Once enviromemtal can be tackled then construction engineering can then promote sustainable development.

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