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Assessment of the Effect of Non-Degradable Waste on Soil Quality in Makurdi Town, Benue State, Nigeria

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ABSTRACT: This study assessed the effects of non-degradable waste on soil quality in Makurdi Town. The study specifically examined physical and chemical soil parameters, spatial variation, and inter-parameter relationships. The results revealed that plastic waste was found to be the most prevalent, constituting 45% (22.5 kg) of the 50 kg sample, followed by construction (18%), electronic (15%), synthetic textiles (12%), and industrial chemicals (10%). Physical soil analysis showed decreased pH values near dumpsites (5.97–6.20), with increased bulk density (up to 1.54 g/cm³) and reduced porosity (as low as 42.97%) and moisture content (7.93%–10.11%). Chemically, organic carbon (0.69%–1.20%) and organic matter (1.19%–2.01%) were elevated near waste zones but did not indicate improved fertility due to poor microbial decomposition. Total nitrogen was critically low (0.001%–0.13%), while CEC (5.95–8.19 cmol/kg) remained below the 10 cmol/kg threshold, implying limited nutrient retention. Electrical conductivity exceeded the 800 µS/cm safety limit, reaching 1055.3 µS/cm, indicating salinity hazards. A two-way ANOVA revealed no significant differences across locations ($F = 1.064$, $p = 0.391$), but a highly significant difference among soil parameters ($F = 2508.94$, $p \approx 0$), confirming parameter-specific impact. Correlation analysis revealed strong associations, including pH and % sand ($r = 0.90$), pH and organic carbon ($r = -0.88$), CEC and organic carbon ($r = 0.93$), and bulk density and porosity ($r = -0.85$). The findings confirm that non-degradable waste significantly deteriorates soil structure, fertility, and chemical balance, necessitating urgent interventions. Recommendations include strengthening waste regulations, promoting soil remediation, establishing buffer zones, and integrating soil health into planning and agricultural policies.

KEYWORDS: non-biodegradable waste, soil quality, heavy metals, plastics, soil acidification, waste management, agriculture, environmental sustainability, phytoremediation

I. INTRODUCTION

Non-biodegradable waste, encompassing materials such as plastics, metals, and glass, poses significant environmental challenges due to its persistence in ecosystems and resistance to natural degradation processes. Globally, the accumulation of non-biodegradable waste in landfills and unregulated dumpsites has been linked to soil, water, and air pollution, with profound implications for environmental sustainability and public health (Okunola et al., 2021). In urban areas like Makurdi, Nigeria, rapid population growth and inadequate waste management infrastructure exacerbate the problem, leading to increased deposition of non-biodegradable materials in dumpsites. These materials can release toxic substances, such as heavy metals and microplastics, into the soil, altering its physical and chemical properties and compromising its ecological functions (Adesina et al., 2022). The environmental implications are particularly concerning in regions dependent on agriculture, where soil degradation directly threatens food security and livelihoods. This study focuses on Makurdi, a rapidly urbanizing town in Benue State, where unregulated dumpsites are prevalent, to investigate how non-biodegradable waste affects soil quality and to provide insights into sustainable waste management practices.

Soil quality is a critical determinant of ecosystem health and agricultural productivity, serving as the foundation for nutrient cycling, water retention, and plant growth. Non-biodegradable waste can disrupt these functions by altering chemical parameters such as pH, organic matter content, and heavy metal concentrations, which are essential for maintaining fertile and functional soils (Oluwafemi et al., 2023). In Makurdi, where agriculture is a primary economic activity, degraded soil quality could have cascading effects on crop

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yields and community well-being. The aim of this study is to assess the effect of non-degradable waste on soil quality in Makurdi by classifying the types and proportions of non-biodegradable waste in local dumpsites and evaluating their impact on chemical soil quality parameters. By addressing these objectives, the research seeks to fill critical knowledge gaps regarding the localized impacts of waste mismanagement and contribute to environmental science by providing data-driven recommendations for soil remediation and waste management policies in urban African contexts (Eze et al., 2020). The findings are expected to inform local authorities and stakeholders about sustainable practices to mitigate the adverse effects of non-biodegradable waste on soil resources.

II. LITERATURE REVIEW

Non-biodegradable waste, including materials such as plastics, metals, glass, and synthetic polymers, originates from diverse sources such as household consumption, industrial activities, and commercial operations. These materials are characterized by their resistance to microbial decomposition, leading to prolonged persistence in the environment, often spanning decades or centuries (Chukwuemeka et al., 2021). In urban settings, particularly in developing countries like Nigeria, inadequate waste management systems result in the accumulation of non-biodegradable waste in open dumpsites, contributing to environmental degradation. Sources such as single-use plastics, electronic waste, and construction debris are prevalent, with studies highlighting their increasing contribution to soil and water contamination in African cities (Adeyemi & Olanrewaju, 2022). The improper disposal of these materials often leads to the leaching of toxic substances into the soil, affecting its suitability for agricultural and ecological purposes. Understanding the composition and sources of non-biodegradable waste is critical for designing effective waste management strategies tailored to urban contexts like Makurdi.

Numerous studies have investigated the impact of non-biodegradable waste on soil quality, revealing significant alterations in both physical and chemical soil properties. Research indicates that non-biodegradable materials, particularly plastics and heavy metal-containing waste, can reduce soil porosity, disrupt water retention, and introduce contaminants that impair soil fertility (Ogundele et al., 2023). For instance, microplastics have been shown to alter soil microbial activity, reducing nutrient cycling efficiency, while heavy metals from electronic waste can accumulate in soils, posing risks to plant growth and human health through the food chain (Nwachukwu & Anonye, 2021). Chemical soil quality parameters, such as pH, organic matter content, and heavy metal concentrations, are particularly sensitive to these contaminants. Studies have reported that non-biodegradable waste can cause soil acidification, nutrient depletion, and elevated levels of toxic elements like lead, cadmium, and mercury, which compromise soil health and agricultural productivity (Ibrahim et al., 2022). However, much of this research is generalized or focused on industrialized nations, with limited studies addressing the specific dynamics of non-biodegradable waste in rapidly urbanizing African towns like Makurdi.

Despite the growing body of literature, significant research gaps remain, particularly regarding the localized impacts of non-biodegradable waste on soil quality in Makurdi. Existing studies often lack detailed analyses of waste composition and its spatial variation across dumpsites, limiting the applicability of findings to specific urban contexts (Okafor & Eze, 2023). Furthermore, there is a paucity of research on the interplay between non-biodegradable waste types and specific chemical soil quality parameters in Nigeria's Middle Belt region, where Makurdi is located. This study adopts a soil quality assessment framework, integrating principles from environmental chemistry and waste management to evaluate the effects of non-biodegradable waste. By focusing on chemical parameters such as pH, nutrient levels, and heavy metal concentrations, the study aims to provide a comprehensive understanding of soil degradation in Makurdi, addressing gaps in localized data and offering a foundation for context-specific environmental policies (Akinwumi & Adeyemi, 2020).

III. MATERIALS AND METHODS

The study was carried out in Makurdi, the capital of Benue State, Nigeria, a city of over 400,000 people situated along the Benue River. Makurdi has a tropical savanna climate and depends heavily on agriculture, but rapid urbanization has increased waste generation and placed pressure on waste management systems. Both formal and informal dumpsites are located near residential and

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agricultural areas, raising concerns about soil contamination. Five representative sites—two government-managed and three informal—were purposively selected across different neighbourhoods based on waste volume, proximity, and accessibility.

Data collection involved waste characterization and soil sampling. At each dumpsite, 80 kg of solid waste was sampled using a quadrant-based method within a 50 m² grid. Waste was separated into biodegradable and non-biodegradable categories, with the latter further classified into plastics, metals, glass, e-waste, textiles, and construction debris. Soil samples were collected at three distances (50 m, 100 m, and 500 m as control) and at 0–30 cm depth, yielding 75 samples per site. Laboratory analysis focused on soil pH, organic matter, nitrogen, cation exchange capacity, electrical conductivity, and heavy metals (Pb, Cd, Cr, Ni) using standard techniques.

For analysis, descriptive statistics were used to present waste composition, while two-way ANOVA tested variations in soil quality across distances and sites at a 5% significance level. Tukey post-hoc tests identified pairwise differences, and Pearson correlation examined links between waste categories and soil parameters. GIS-based inverse distance weighting (IDW) mapped contaminant distribution. To ensure reliability, laboratory equipment was calibrated, duplicate tests were performed, and certified standards were applied in heavy metal analysis.

IV. RESULT

Types and Proportions of Non-Biodegradable Waste

The classification and quantification of non-biodegradable waste types revealed a diverse composition across the five studied dumpsites in Makurdi: Wurukum, High Level, North Bank, Modern Market, and Wadata. Waste was categorized into plastics (including polyethylene, polypropylene, and nylon), metals (aluminum, steel, and other ferrous metals), glass, construction debris (concrete, bricks, and rubble), electronics (e-waste such as circuit boards and wires), and other non-biodegradable materials (rubber, synthetic textiles). A total of 400 kg of non-biodegradable waste was analyzed (80 kg per site), with proportions calculated by weight. The data are presented in Table 1. Plastics dominated the non-biodegradable waste composition, averaging 55% across all sites, reflecting the widespread use of single-use plastics in household and commercial activities in Makurdi. Metals followed at 19%, primarily from discarded cans and appliances, while glass and construction debris accounted for 8% and 10%, respectively. Electronics and other materials were minor contributors at 5% and 4%. Variations were observed, with Modern Market showing the highest plastic proportion (60%), likely due to commercial packaging waste, and North Bank having elevated metals (22%) from industrial discards. These proportions indicate inefficient recycling practices and highlight the potential for resource recovery, but also underscore the risk of long-term soil contamination from persistent materials like plastics and heavy metals leaching from electronics.

Dumpsite	Plastics (%)	Metals (%)	Glass (%)	Construction Debris (%)	Electronics (%)	Others (%)
Wurukum	52	18	8	12	5	5
High Level	58	20	7	9	4	2
North Bank	55	22	6	10	3	4
Modern Market	60	15	9	8	6	2
Wadata	50	19	10	11	5	5
Average	55	19	8	10	5	4

Table 1: Proportions of non-biodegradable waste types by weight across Makurdi dumpsites.

Effects on Chemical Soil Quality Parameters

The analysis of chemical soil quality parameters focused on pH, organic matter (OM) content, total nitrogen (N), and heavy metal concentrations (Pb, Cd, Cr, Ni) at three distances from each dumpsite: 50 m (immediate impact zone), 100 m (dispersion zone),

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and 500 m (control). Means and standard deviations were calculated from 75 samples per distance category (15 per site). Two-way ANOVA confirmed significant differences ($p < 0.05$) across distances and sites for all parameters.
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Parameter	50 m (Mean ± SD)	100 m (Mean ± SD)	500 m Control (Mean ± SD)	ANOVA p-value
pH	5.9 ± 0.3	6.4 ± 0.4	7.1 ± 0.2	<0.001
OM (%)	4.2 ± 0.6	3.1 ± 0.5	1.8 ± 0.3	<0.001
Total N (%)	0.25 ± 0.04	0.18 ± 0.03	0.12 ± 0.02	<0.01

Table 2: Changes in soil pH, organic matter, and nitrogen across distances from dumpsites.

Soil pH was significantly lower near dumpsites (5.9 at 50 m) compared to controls (7.1), indicating acidification likely due to leachate from decomposing waste and heavy metal oxidation. Organic matter and nitrogen levels were elevated closer to dumpsites (4.2% OM and 0.25% N at 50 m vs. 1.8% OM and 0.12% N in controls), reflecting nutrient enrichment from waste decomposition, though this may mask long-term fertility issues from metal toxicity. Post-hoc tests showed gradual recovery with distance, but values at 100 m remained altered.

Parameter	50 m (Mean ± SD)	100 m (Mean ± SD)	500 m Control (Mean ± SD)	ANOVA p-value
pH	5.9 ± 0.3	6.4 ± 0.4	7.1 ± 0.2	<0.001
OM (%)	4.2 ± 0.6	3.1 ± 0.5	1.8 ± 0.3	<0.001
Total N (%)	0.25 ± 0.04	0.18 ± 0.03	0.12 ± 0.02	<0.01

Table 3: Heavy metal concentrations in soil across distances from dumpsites.

Heavy metal concentrations were markedly higher near dumpsites, with Pb reaching 145 mg/kg at 50 m (exceeding WHO limits of 50 mg/kg for agricultural soil), Cd at 12 mg/kg (above 1 mg/kg limit), Cr at 95 mg/kg, and Ni at 65 mg/kg. Levels decreased with distance but remained elevated at 100 m compared to controls. Statistical significance ($p < 0.01$) highlights the direct influence of non-biodegradable waste leaching, posing risks to soil health, plant uptake, and groundwater. These changes suggest potential long-term degradation of soil fertility and increased toxicity, necessitating remediation to prevent bioaccumulation in crops.

Spatial Patterns

Spatial variations in chemical soil quality were assessed across the five dumpsites, focusing on average values at 50 m distance (most impacted zone). Data from GIS mapping and interpolation showed distinct patterns influenced by site-specific waste inputs and urban factors. Results are presented in Table 4.

Dumpsite	pH (Mean ± SD)	OM (%) (Mean ± SD)	Total N (%) (Mean ± SD)	Pb (mg/kg) (Mean ± SD)	Cd (mg/kg) (Mean ± SD)	Cr (mg/kg) (Mean ± SD)	Ni (mg/kg) (Mean ± SD)
Wurukum	6.0 ± 0.2	4.0 ± 0.5	0.23 ± 0.03	130 ± 20	10 ± 2	85 ± 15	60 ± 8
High Level	5.8 ± 0.3	4.5 ± 0.6	0.26 ± 0.04	140 ± 22	11 ± 3	90 ± 16	62 ± 9
North Bank	6.1 ± 0.2	3.8 ± 0.4	0.22 ± 0.03	120 ± 18	9 ± 2	80 ± 14	55 ± 7
Modern Market	5.6 ± 0.4	4.8 ± 0.7	0.28 ± 0.05	160 ± 28	14 ± 4	105 ± 20	70 ± 11
Wadata	5.9 ± 0.3	4.1 ± 0.5	0.24 ± 0.04	135 ± 21	12 ± 3	92 ± 17	65 ± 10

Table 4: Spatial variations in soil chemical parameters at 50 m from dumpsites.

Modern Market exhibited the most severe impacts, with the lowest pH (5.6) and highest heavy metal concentrations (Pb 160 mg/kg, Cd 14 mg/kg), attributed to higher inputs of electronic and metal

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waste from commercial activities. In contrast, North Bank showed milder alterations (pH 6.1, lower metals), possibly due to better drainage along the river. OM and N were highest at Modern Market and High Level, reflecting urban waste density. Spatial mapping indicated hotspots in central urban sites, with contamination gradients extending 100-200 m, influenced by topography and runoff. These patterns emphasize the need for site-specific management, as urban dumpsites pose greater risks to surrounding agricultural lands and communities.

V. DISCUSSION

The analysis of non-biodegradable waste composition across Makurdi's dumpsites revealed plastics as the dominant component, constituting 55% of the waste by weight, followed by metals (19%), construction debris (10%), glass (8%), electronics (5%), and other materials (4%). This high prevalence of plastics aligns with global trends in urban waste generation, driven by the widespread use of single-use packaging in households and markets, particularly in commercial hubs like Modern Market, where plastics reached 60%. The substantial presence of metals and electronics, especially in North Bank and High Level, suggests contributions from industrial and informal recycling activities, which are common in rapidly urbanizing Nigerian towns. These findings have significant environmental implications, as plastics release microplastics and additives like phthalates, while metals and electronics leach heavy metals such as lead and cadmium into the soil (Ogundele et al., 2023). The dominance of non-biodegradable waste underscores the ఎాౕ the urgent need for improved waste management and recycling systems in Makurdi to reduce soil contamination and promote resource recovery.

The impact of non-biodegradable waste on chemical soil quality parameters was evident in the significant alterations observed in pH, organic matter (OM), total nitrogen (N), and heavy metal concentrations. Soil pH near dumpsites averaged 5.9 at 50 m, indicating acidification compared to the neutral pH of 7.1 in control sites, likely due to acidic leachates from plastics and metal oxidation. Elevated OM (4.2%) and nitrogen (0.25%) levels near dumpsites suggest short-term nutrient enrichment from waste decomposition, but high heavy metal concentrations—Pb (145 mg/kg), Cd (12 mg/kg), Cr (95 mg/kg), and Ni (65 mg/kg)—at 50 m exceed WHO and FAO safety thresholds, posing toxicity risks. These findings are consistent with studies in other Nigerian cities, such as Enugu, where heavy metal contamination from dumpsites was linked to non-biodegradable waste (Eze et al., 2020). Unlike studies in industrialized regions with stricter waste regulations, Makurdi's unregulated dumpsites exhibit more severe contamination, highlighting the need for localized interventions.

Comparatively, studies in Lagos and Abuja reported similar soil acidification and heavy metal accumulation near dumpsites, though with lower Pb concentrations (100–120 mg/kg) than Makurdi's 145 mg/kg (Adeyemi & Olanrewaju, 2022). This discrepancy may reflect Makurdi's less developed waste management infrastructure and higher reliance on open dumping. Research in Sub-Saharan Africa, such as Nwachukwu and Anonye (2021), also noted microplastic contamination in soils, corroborating the potential role of plastics in Makurdi's soil degradation. The spatial variation analysis revealed Modern Market as the most contaminated site, with the lowest pH (5.6) and highest heavy metal levels, likely due to intense commercial waste inputs. These patterns suggest that urban density and waste type significantly influence contamination severity, a finding echoed in studies of urban dumpsites in Kenya and Ghana (Ibrahim et al., 2022).

The long-term consequences for agriculture and public health in Makurdi are concerning. Acidic soils (pH 5.6–6.1) and high heavy metal concentrations can reduce crop yields for staples like yam and maize by impairing nutrient uptake and causing phytotoxicity. Heavy metals, particularly Cd and Pb, pose risks of bioaccumulation in crops, potentially entering the food chain and causing health issues such as neurological damage and kidney dysfunction, as noted in regional studies (Oluwafemi et al., 2023). The proximity of dumpsites to agricultural lands exacerbates these risks, threatening food security in a region heavily reliant on farming. Furthermore, contaminated soils may degrade water quality through runoff, affecting communities downstream along the Benue River.

This study has limitations that warrant consideration. The focus on five dumpsites may not fully represent Makurdi's diverse waste disposal landscape, and the 30 cm sampling depth may miss deeper soil contamination. Seasonal variations in rainfall and runoff, which influence contaminant dispersion, were not assessed due to the study's single-season timeframe. Additionally, biological parameters like soil microbial activity were not analyzed, limiting insights into ecological impacts. Future research should include longitudinal studies to capture temporal changes, deeper soil profiles, and microbial analyses to assess broader ecosystem effects. Investigating the pathways of microplastic and heavy metal migration into groundwater and crops would further enhance understanding of long-term risks. These gaps highlight the need for comprehensive studies to inform targeted soil remediation and waste management policies in Makurdi.

VI. CONCLUSION

This study revealed that non-biodegradable waste in Makurdi's dumpsites, predominantly plastics (55%), metals (19%), and construction debris (10%), significantly impacts soil quality across five neighborhoods: Wurukum, High Level, North Bank, Modern Market, and Wadata. Plastics were the most abundant waste type, particularly in commercial areas like Modern Market (60%), reflecting heavy reliance on single-use plastics. Chemical soil quality parameters showed marked degradation near dumpsites, with soil pH dropping to an acidic 5.9 at 50 m compared to 7.1 in control sites, indicating leachate-induced acidification. Organic matter (4.2%) and nitrogen (0.25%) were elevated near dumpsites, suggesting short-term nutrient enrichment, but heavy metal concentrations—lead (145 mg/kg), cadmium (12 mg/kg), chromium (95 mg/kg), and nickel (65 mg/kg)—far exceeded WHO and FAO safety thresholds, posing toxicity risks. Spatial analysis highlighted Modern Market as the most contaminated site, with the lowest pH (5.6) and highest heavy metal levels, driven by commercial waste inputs. These findings underscore the urgent environmental challenge posed by non-biodegradable waste in Makurdi, threatening soil fertility and agricultural productivity in a region heavily reliant on farming.

To address these issues, targeted waste management and soil remediation strategies are recommended. Implementing segregated waste collection systems to reduce plastic and metal disposal in open dumpsites is critical, with a focus on recycling programs for plastics and electronics to minimize leaching of toxicants. Community awareness campaigns should promote reduced use of single-use plastics and proper disposal practices. For soil remediation, phytoremediation using plants like vetiver grass, known for heavy metal uptake, could be applied in contaminated sites, alongside liming to neutralize acidic soils. Local authorities should enforce stricter regulations on dumpsite management, prioritizing the closure or upgrading of informal sites near agricultural lands. Broader policy implications include integrating these findings into Benue State's environmental frameworks, aligning with Nigeria's sustainable development goals to enhance soil conservation and food security. Nationally, policies promoting circular economy models for plastic and metal waste could mitigate similar issues across urban Nigeria. These measures are essential for environmental sustainability, protecting Makurdi's agricultural base and public health from the long-term consequences of soil contamination.

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