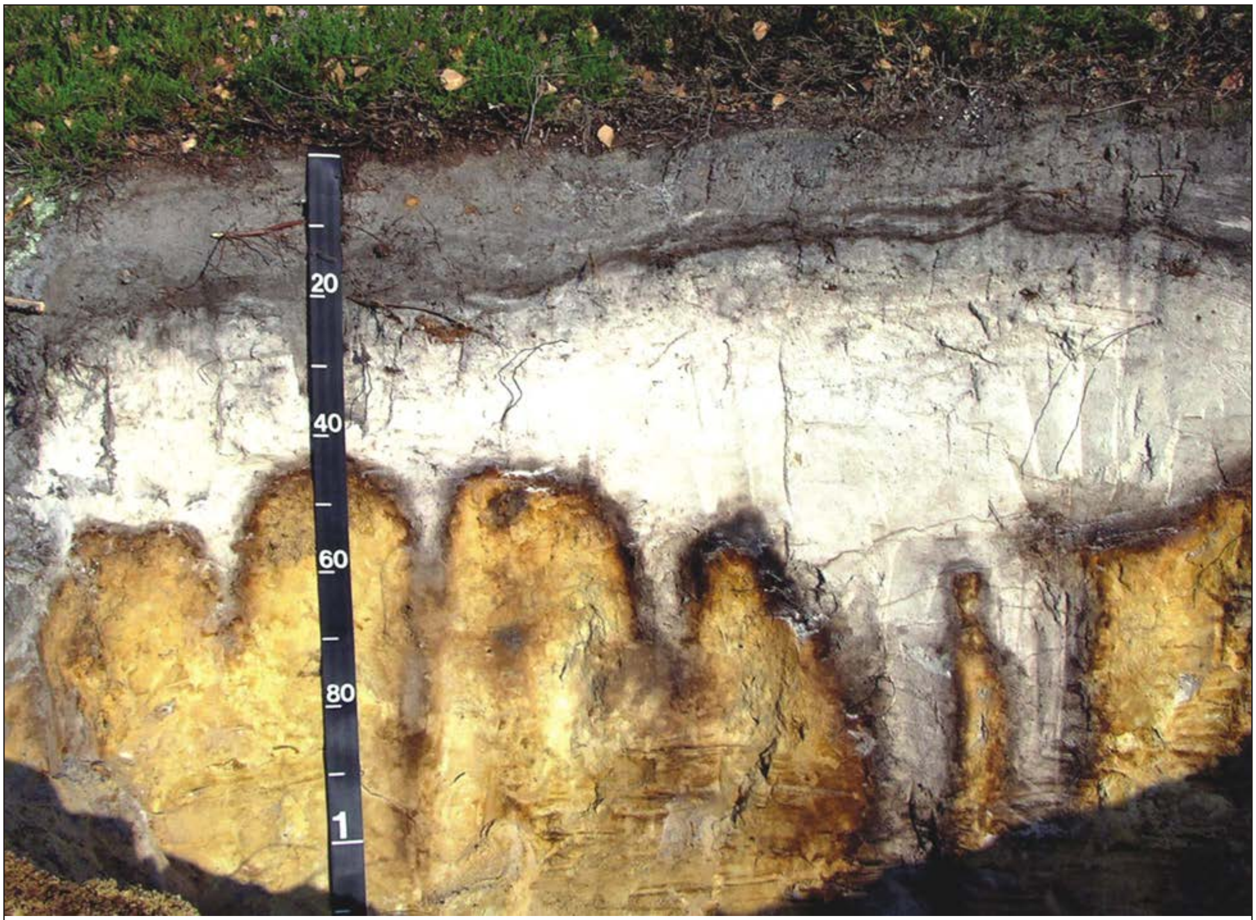

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Research Article
Physicochemical Properties of Technosols in Dumpsites of Enugu Urban Southeastern, Nigeria

Martin Atu Ngozika Anikwe and Cynthia Kosiso Anigbo

Department of Agronomy and Ecological Management, Enugu State University of Science and Technology, Agbani, Enugu, Nigeria

Abstract
Background and Objective: Human activities have produced artificial soils with pedogenesis dominated by their technological origin. This study compared Technosols' physicochemical qualities at Eke Market Dumpsite, Agbani (6°18'24"N, 7°32'52"E) and Abakpa Bridge Head Dump Site (6°28'34"N, 7°31'02"E) in Enugu Southeast, Nigeria to characterize and compare differences in some of their physicochemical properties. **Materials and Methods:** Profile pits were dug within the dumpsite of the selected areas and corresponding control pits for both sites were dug 100 m away. Samples were collected from the depth of the observable horizon in each profile. The coefficient of variation was used to analyze the data collected. **Results:** The dumpsites and non-dumpsites of two sandy loam-sandy clay loam sites have similar particle size distributions. The pH (H_2O) was slightly alkaline at dumpsites (7.4-7.6) compared to 5.6-6.3 for non-dumpsites. Soil organic carbon in the top 0-50 cm of the dump soil (1.49-4.6%) was 91-96% greater than in the same horizon of the non-dump soil (0.07-0.39%) for both sites, although topsoil OC varied greatly. The dump site has 32% higher total nitrogen in the top 100 cm of soil than the non-dump site (0.13-0.25%). The CEC values of 16.0-24.4 cmol kg^{-1} were greater in dumpsite soils than in non-dump site soils (12.4-14.8 cmol kg^{-1}). Base saturation in the vadose zone of dumpsite soils ranged from 27.6 to 46.8%, compared to 10.9-22.8% in non-dump soils at both sites. **Conclusion:** The vadose zone of dump site soils has greater exchangeable cation levels than non-dump sites. Technosols alleviate land degradation and green challenges. The soil quality assessment helps track Technosol changes and evaluate pedogenetic processes. Under tropical conditions, municipal waste Technosols may have a beneficial effect on agricultural soil quality.

Key words: Technosols, soil properties, dumpsites, technological origin, Enugu urban, Southeast Nigeria

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Corresponding Author: Martin Atu Ngozika Anikwe, Department of Agronomy and Ecological Management, Enugu State University of Science and Technology, Agbani, Enugu, Nigeria

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The soil is the natural plant growth substrate, providing minerals, nutrients and water. Each soil has diverse types/ components, providing unique features that affect plant growth response, fertilizer requirement, drainage, land use capabilities etc[1]. The components of a mineral-based soil include inorganic particles, organic matter, living organisms, water and air, as well as their physical properties, chemical properties and nutrient availability. Technosols are assemblages of soils whose pedogenesis and characteristics are determined by their technical origin. Technosols are characterized by their physical properties, chemical properties and nutrient availability. Artifacts in the soil include geomembrane-covered soils and soils made from waste materials, such as landfills, sewage, ashes, mining and ruins. Technosols are urban or mined soils[2].

Municipal solid wastes are undesired items from home waste, industrial firms, hotels, schools, public services, markets and trade and hospitals, often thrown on open land in underdeveloped countries[3]. Waste products have increased in quantity and variety due to technology and population growth, leading to environmental sanitation issues. Nigeria produces a million to a thousand tons of solid trash daily, often dumped in vacant areas or at dumping sites. Organic amendments are becoming increasingly popular for restoring soil organic matter and improving soil quality[4].

Technosols offer various ecosystem services, including provision, regulation and cultural services. They can retain sustainable plant cover, minimize soil and water erosion, restrict pollutant dispersion and create an appropriate aesthetic feature[5].

Technosols are distinguished by their technogenic origin and these soils' pedogenesis is poorly understood. Research and development are being focused on optimizing ecosystem services offered by Technosols in urbanized settings, with local stakeholder participation[6]. Productivity is the primary ecosystem service in agroecosystems, while environmental quality and biodiversity conservation are the primary objectives in natural ecosystems[7]. Urban soils contain anthropogenic materials and artifacts, such as construction rubble and building detritus, which significantly impact natural soil processes. The addition of anthropogenic materials that alter soil characteristics, as well as the potential applications and ecosystem services they may provide, have a substantial influence on several urban soils[8,9]. Further experimental study of the effect of organic amendments on soil properties and the determination of the impact of wastes and their contaminant effects on soil is essential for monitoring the environmental impact of waste and developing techniques to combat soil pollutants.

This study examines some of the physicochemical properties of Technosols developing under the impact of municipal waste dumping in Enugu urban Southeastern Nigeria. Specifically, the study will determine and compare the variations in pH levels, organic matter content, CEC, total nitrogen and macro and micro-nutrients between natural and dumpsite soils. This will be valuable in determining the quality monitoring indicators that are most appropriate for evaluating the prospective usage of Technosols for a sustainable, green city.

MATERIALS AND METHODS

Study area: The experiment was carried out in March-September, of 2021/2022 farming season in the municipal dumpsites of Eke Market in Agbani, Nkanu West (6°18'24"N, 7°32'52"E) and Abakpa Bridge Head, Abakpa Nike (6°28'34.36"N, 7°31'2.62"E) in Enugu State which lies in the Southeast Geopolitical Zone in Nigeria. The non-dump site control plots were located at a distance of 100 m away from each of the municipal dumpsites. The location of the study sites was shown in Fig. 1 and 2.

The study area was characterized by a complex terrain dominated by a high elevation, ranging from 232 m above sea level. The region often receives a bimodal rainfall pattern with dry periods in August, distributed from April to July and September to November. The mean annual rainfall is 1880 mm, while the lowest and maximum amounts vary from 1700 to 2060 mm. The cold (harmattan) season ranges from 27 to 31°C, often between December and March. When it rains, the relative humidity is at its peak (80%), but when it stops, it drops to 60%[9]. The ultisols dominate the study area, with Typic paleusult in the upper slope areas and Typic paleudults in the lower elevation. Municipal trash has been dumped at the two study locations for over twenty years. Around 8 to 10 tons of unsorted waste from the municipality, primarily made up of family and industrial effluents like food scraps and leaf litter, paper goods, rags, plastic/polyethene, tins and metallic substances, containers, glasses, laboratory wastes and an assortment of other various components, are dumped weekly at each site (each measuring close to one hectare)[10].

Field sampling and collection: Sampling was carried out during the dry season using the free survey technique. The surveyor chooses observation points that are representative of the site based on personal judgment and experience[11]. Each profile pit measured 150×50×150 cm^3 (length×depth× width). Three auger samples were collected from each horizon in all the sites for laboratory analyses.

Fig. 1: Location of the Eke, Agbani study area municipal waste dump site

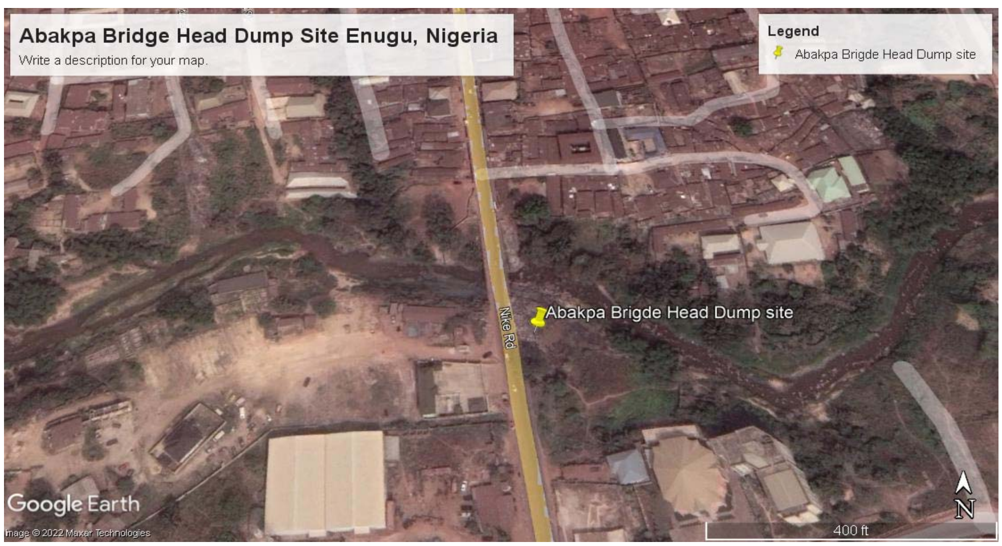

Fig. 2: Location of the Abakpa Bridge Head Dump Site Enugu

The auger samples were composited. The samples were analyzed in the Department of Soil Science, the University of Nigeria, Nsukka's Research Laboratory for particle size distribution, exchangeable acidity, organic carbon content, pH in water, total nitrogen, available P and cation exchange.

Soil sample analysis: All collected soil samples from each site were air-dried, crushed and sieved through a 2 mm mesh. The following soil properties were determined in the collected samples: Soil textural class names were provided in line with the United States Department of Agriculture (USDA) classification[12]. Particle size analysis was determined by the hydrometer method using Royal Eijkelkamp Hydrometer (ASTM D422 and AASHTO T 88 The Netherlands) as described by Gee and Or[13] and Total N was determined using the macro Kjeldahl method[14] using Macro-Kjeldahl apparatus (VELP Scientifica, Italy). The soil organic C content was determined using the Walkley-Black dichromate oxidation procedure[15] using Total Organic Carbon (TOC) PT by Merck Germany, pH (in water) was determined by the method of McLean[16] using pH meter set for soil and water 18.86 Eijkelkamp, Netherlands, Exchangeable acidity was determined by the method proposed by Dewis and Freitas[17]. Exchangeable bases (Ca, Mg, K and Na) were extracted using ammonium acetate solution and determined using atomic absorption spectrophotometer (SP-IAA1800H/Bioevopeak, China) as described by Westerman[18].

Statistical analysis: The data collected were analyzed using the coefficient of variation (CV) to measure the variability that indicates the size of a standard deviation about its mean as postulated by Steel and Torrie[19].

RESULTS AND DISCUSSION

Differences in particle size distribution and texture of Technosol in a selected dumpsite in Enugu urban: Some selected physical properties of soils in the dump and non-dump sites of the selected area (Eke Market Dumpsite, Agbani and the Abakpa Bridge Head Dump Site) were shown in Table 1. Three soil horizon depths of 0-50, 50-97 and 98-120 cm were identified for the Eke market dump site, with total sand values of 81, 69 and 67%, respectively (Table 1). In contrast, the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm with % sand contents of 75, 76 and 77%, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54 , 54-88 and 88-120 cm were identified with total sand values of 57, 72 and 65%, respectively. In contrast, the horizon depths of the non-dumpsite soils were 4 and ranged from 0-30, 30-59, 59-103 and 103-120 cm with % sand contents of 63, 63, 73 and 75%, respectively.

Three soil horizon depths of 0-50, 50-97 and 98-120 cm for the Eke market dump site had total silt values of 5, 7 and 7%, respectively. In contrast, the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm with % silt contents of 5, 3 and 7%, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54, 54-88 and 88-120 cm had total silt values of 25, 11 and 9%, respectively. In contrast, the horizon depth of the non-dump site soils were 4 and ranged from 0-30, 30-59, 59-103 and 103-120 cm with % silt contents of 13, 13, 7 and 11%, respectively.

Similarly, three soil horizon depths of 0-50 , 50-97 and 98-120 cm for the Eke market dump site had total percent clay values of 14, 24 and 26%, respectively. In contrast, the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm with % clay contents of 20, 20 and 16%, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54, 54-88 and 88-120 cm had total clay values of 18, 16 and 26%, respectively. In contrast, the horizon depth of the non-dump site soils were 4 and ranged from 0-30, 3 0-59, 59-103 and 103-120 cm with % clay contents of 24, 24, 20 and 14%, respectively. These results showed a coefficient of variation of between 8.1 to 47.5% relative to the means and therefore depicting significant variation in the particle size distribution of the different horizons of the dump and non-dump soils studied. The results showed that in most

Table 1: Differences in particles size distribution and texture between the dumpsite and non-dumpsite soil

Eke Market Dumpsite, Agbani				Abakpa Bridge Head Dump Site			
Horizon depth (cm)	Dumpsite	Horizon depth (cm)	Non-Dumpsite	Horizon depth (cm)	Dumpsite	Horizon depth (cm)	Non-dumpsite
Sand (%)							
0-50	81	0-35	75	0-54	57	0-30	63
50-97	69	5-69	76	54-88	72	30-59	63
97-120	67	69-120	77	88-120	65	59-103	73
						103-120	75
CV(%)	8.5		1.1		9.5		8.1
Silt (%)							
0-50	5	0-35	5	50-54	25	0-30	13
50-97	7	35-69	3	54-88	11	30-59	13
97-120	7	69-120	7	88-120	9	59-103	7
						103-120	11
CV(%)	14.8		32.6		47.5		22.3
Clay (%)							
0-50	14	0-35	20	0-54	18	0-30	24
50-97	24	35-69	20	54-88	16	30-59	24
97-120	26	69-120	16	88-120	26	59-103	20
						103-120	14
CV(%)	24.6		10.1		21.6		19.9
Texture (%)							
0-50	SL	0-35	SL	0-54	SL	0-30	SCL
50-97	SCL	35-69	SL	54-88	SL	30-59	SCL
97-120	SL	69-120	SL	88-120	SL	59-103	SL
						103-120	SL

SL: Sandy loam, SCL: Sandy clay loam and CV: Coefficient of variation cases, the long-term dumping of municipal wastes influenced the pedogenic processes, thus altering the particle size distribution of the dump site soils relative to the non-dump site soils. Generally, the average percent sand in the 0-120 cm layer of both non-dump sites was between 68-76% versus 64-72% in the dump site. The textural class of the selected dumpsite soils was predominately Sandy Loam in the first soil layer of Eke Market Dumpsite, Agbani and a Sandy Clay Loam in the second layer, whereas the Abakpa Bridge Head Dump Site was Sandy Loam throughout the three layers. In contrast, the non-dump soils were predominately Sandy Loam for the Eke Market, Agbani non-dump site and Sandy Clay Loam for the first and second layers of the Abakpa non-dump site, with the third and fourth layers dominated by Sandy Loam. However, Loughry[20] advocated sandy loam soils for locations for waste disposal due to their suitability for allowing significant amounts of leachates to permeate through the soil, soils that include more than 70% sand are wildly inappropriate for trash dumping. Additionally, since they increase surface flooding and contamination from surface runoff, soils with clay and silt contents higher than 31% are unsuitable for garbage disposal.

Organic carbon, pH and available phosphorus content of Technosols in dumpsites of Enugu urban: The chemical properties of Technosols in dumpsites of Enugu urban were shown in Table 2-4. The organic carbon levels were characterized by relatively large variability. Results showed that the three soil horizon depths of 0-50, 50-97 and 98-120 cm identified for the Eke market dump site had total % OC values of 4.6, 0.33 and 0.39%, respectively (Table 2). In contrast, the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm with % OC contents of 0.39, 0.43 and 0.36%, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54, 54-88 and 88-120 cm were identified with total OC values of 1.49, 0.49 and 0.53 %, respectively. In contrast, the horizon depths of the non-dump site soils were 4 and ranged from 0-30, 30-59, 59-103 and103-120 cm with % OC contents of 0.07, 0.13, 0.49 and 0.50 %, respectively. Prout *et al.*[21], classified organic matter in this research site as low (values less than critical limits), medium (values above critical limits) and high (values exceeding 3.1%). Large quantities of organic carbon and organic matter in the top layer of the dumpsites were triggered by the land's usage for municipal waste disposal. The high total organic carbon concentration in the top layer of landfill soil indicates increased microbial activity in landfill soils, which results in the release of organic carbon and acidic chemicals[22]. Organic matter is a reservoir of essential and non-essential mineral elements for plant growth and development, thus, increased organic matter content may lead to increased soil productivity, as it contributes significantly to the physicochemical activity of soils, particularly those with lower clay content[23].

Table 2: Differences in organic carbon (%), total nitrogen (%), available Phosphorus (cmol kg^{-1}) and pH in water (H_2O) between dump and non-dump soils

Eke Market Dumpsite, Agbani				Abakpa Bridge Head Dump Site			
Horizon depth (cm)	Dumpsite	Horizon depth (cm)	Non-Dumpsite	Horizon depth (cm)	Dumpsite	Horizon depth (cm)	Non-dumpsite
OC (%)							
0-50	4.6	0-35	0.39	0-54	1.49	0-30	0.07
50-97	0.33	35-69	0.43	54-88	0.49	30-59	0.13
97-120	0.39	69-120	0.36	88-120	0.53	59-103	0.49
						103-120	0.50
CV (%)	112.4		7.7		65.5		66.7
N (%)							
0-50	0.34	0-35	0.13	0-54	0.32	0-30	0.25
50-97	0.31	35-69	0.14	54-88	0.29	30-59	0.25
97-120	0.25	69-120	0.17	88-120	0.22	59-103	0.15
						103-120	0.49
CV (%)	11.1		13.3		14.3		44.8
Available P (cmol kg^{-1})							
0-50	15.92	0-35	8.46	0-54	14.99	0-30	10.33
50-97	14.06	35-69	14.99	54-88	9.39	30-59	13.12
97-120	9.46	69-120	16.26	88-120	9.39	59-103	14.46
						103-120	16.86
CV (%)	20.7		23.1		23.5		25.9
pH-H_2O							
0-50	7.4	0-35	5.6	0-54	7.3	0-30	5.2
50-97	7.8	35-69	5.6	54-88	7.5	30-59	5.4
97-120	7.6	69-120	5.5	88-120	7.5	59-103	5.4
						103-120	5.8
CV (%)	2.1		0.9		1.2		13.3

Table 3: Differences in CEC (cmol kg^{-1}) and percent base saturation between dump and non-dump soils

Eke Market Dumpsite, Agbani				Abakpa Bridge Head Dump Site			
Horizon depth (cm)	Dumpsite	Horizon depth (cm)	Non-Dumpsite	Horizon depth (cm)	Dumpsite	Horizon depth (cm)	Non-dumpsite
CEC (cmol kg^{-1})							
0-50	16.0	0-35	12.4	0-54	24.4	0-30	14.8
50-97	17.6	35-69	16.4	54-88	14.8	30-59	14.8
97-120	17.6	69-120	12.8	88-120	15.6	59-103	10.0
						103-120	8.0
CV (%)	4.4		12.9		23.8		25.1
BS (%)							
0-50	46.8	0-35	11.9	0-54	37.5	0-30	19.2
50-97	27.7	35-69	10.2	54-88	27.6	30-59	22.1
97-120	29.9	69-120	13.1	88-120	32.7	59-103	22.8
						103-120	36.0
CV (%)	24.5		10.2		12.4		25.9

Table 4: Differences in Exchangeable (Na^+, K^+, Ca^{2+} and Mg^{2+}) bases (cmol kg^{-1}) between dump and non-dump sites

Eke Market Dumpsite, Agbani				Abakpa Bridge Head Dump Site			
Horizon depth (cm)	Dumpsite	Horizon depth (cm)	Non-dumpsite	Horizon depth (cm)	Dumpsite	Horizon depth (cm)	Non-dumpsite
Na^+ (cmol kg^{-1})							
0-50	0.13	0-35	0.02	0-54	0.06	0-30	0.01
50-97	0.02	35-69	0.02	54-88	0.02	30-59	0.02
97-120	0.02	69-120	0.02	88-120	0.03	59-103	0.02
						103-120	0.02
CV (%)	83.3		0		60		22
K^+ (cmol kg^{-1})							
0-50	0.16	0-35	0.06	0-54	0.10	0-30	0.03
50-97	0.05	35-69	0.06	54-88	0.06	30-59	0.05
97-120	0.05	69-120	0.05	88-120	0.07	59-103	0.06
						103-120	0.06
CV (%)	57.8		7.8		21.3		24.0
Ca^{2+} (cmol kg^{-1})							
0-50	0.6	0-35	1.0	0-54	1.6	0-30	1.0
50-97	0.6	35-69	1.0	54-88	0.6	30-59	0.6
97-120	1.6	69-120	1.0	88-120	0.4	59-103	0.6
						103-120	1.0
CV (%)	50.5		0		60.3		25
Mg^{2+} (cmol kg^{-1})							
0-50	6.6	0-35	0.4	0-54	7.4	0-30	1.8
50-97	4.2	35-69	0.6	54-88	3.4	30-59	2.6
97-120	3.6	69-120	0.6	88-120	4.65	9-103	1.6
						103-120	1.8
CV (%)	26.9		17.7		32.8		19.7

Exchangeable Bases: Na^+: Sodium ion, K^+: Potassium ion, Ca^{2+}: Calcium ion, Mg^{2+}: Magnesium ion

The percent nitrogen levels were characterized by relatively medium to large variability. Results show that the three soil horizon depths of 0-50, 50-97 and 98-120 cm identified for the Eke market dump site had total % N values of 0.34, 0.31 and 0.25%, respectively (Table 2). In contrast, the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm with % N contents of 0.13, 0.14 and 0.17%, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54 , 54-88 and 88-120 cm were identified with total N values of 0.32, 0.29 and 0.22%, respectively. In contrast, the horizon depths of the non-dump site soils were 4 and ranged in 0-30, 30-59, 59-103 and 103-120 cm soil horizons with % N contents of 0.25, 0.25, 0.15 and 0.10%, respectively. Comparatively, the soil N content decreased with soil depth for the dumpsites, whereas higher soil N content was found in the lower layers of the non-dumpsite soils. The study area's nitrogen concentrations have been classified as follows: Low (less than 0.15%), medium (0.15-0.20%) and high (more than 0.20%)[21]. According to Landon[24], who rated the total N status as >1% as very high, 0.5-1.0% as high, 0.2-0.5% medium, 0.1-0.2% low and 0.1% as very low, the high nitrogen content of the dumpsite soils may be attributable to the presence of more soil organisms that aid in the breakdown of organic matter.

The available P (cmol kg^{-1}) levels were characterized by relatively medium to considerable variability. Results showed that the three soil horizon depths of 0-50, 50-97 and 98-120 cm identified for the Eke market dump site had available P (cmol kg^{-1}) values of 15.92, 14.06 and 9.46, respectively (Table 2). In contrast, the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm, with available P (cmol kg^{-1}) of 8.46, 14.99 and 16.26, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54 cm, 54-88 cm and 88-120 cm were identified with available P (cmol kg^{-1}) values of 14.99, 9.39 and 9.39, respectively. In contrast, the horizon depths of the non-dump site soils were 4 and ranged from 0-30, 30-59, 59-103 and 103-120 cm with available P (cmol kg^{-1}) contents of 10.33, 13.12, 14.46 and 16.86, respectively. Comparatively, the soil available P (cmol kg^{-1}) decreased with soil depth for the dumpsites, whereas higher soil available P (cmol kg^{-1}) content was found in the lower layers of the non-dumpsite soils indicating stratification of P in both the dump and non-dump soils. The stratification ratio (SR) is a good indicator of the quantitative evaluation of the soil nutrient variation with depth, which is interrelated with nutrient cycles and agricultural productivity[23]. These findings could be attributed to phosphate leaching down the profile as a result of the coarse soil, the high phosphorus content of the parent material, erosion of P-carrying particles, P dissolved in surface runoff[25] and slightly acidic soils that promote P-availability in the non-dumpsite area. This conclusion agreed with the findings of Meyer *et al.*[26], who found that soil conditions significantly impacted P availability.

The pH-H_2O levels were characterized by relatively low to medium variability. Results showed that the three soil horizon depths of 0-50, 50-97 and 98-120 cm in the Eke market dump site had pH-H_2O values of 7.4, 7.8 and 7.6, respectively (Table 2). In contrast, the soil pH-H_2O in the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm, with pH-H_2O of 5.6, 5.6 and 5.5, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54, 54-88 and 88-120 cm were identified with pH-H_2O values of 7.3, 7.5 and 7.5, respectively. In contrast, the horizon depths of the non-dump site soils were 4 and ranged from 0-30, 30-59, 59-103 and 103-120 cm with pH-H_2O of 5.2, 5.4, 5.4 and 5.8, respectively. The pH of the dumpsites area is considered slightly alkaline, with an average reading of 7.6 and 7.4, whereas that of the non-dump site areas was slightly acidic for both Eke market, Agbani and Abakpa Bridge Head dumpsites, respectively. According to Landon[24], many crops may grow in soil with a pH of 6.0 to 8.0. The presence of large amounts of organic matter, which tends to buffer the soil by limiting the pH shift brought on by the release of exchangeable cations during the mineralization of organic matter, maybe the source of the elevated pH in the dumpsites[27]. The availability of nutrients to plants from the soil is at its highest around pH 6.5, according to research, which has been described as a simple and direct indicator of the total chemical condition of the soil[27]. The high pH (alkaline in reaction) of the dumpsite soils results from the accumulation of organic matter. This suggested that the accumulation of organic solid waste could substantially lower soil acidity. The soil under dump sites was significantly more alkaline than those under non-dump sites.

Cation exchange capacity (CEC) and base saturation content of Technosols in dumpsites of Enugu urban: The CEC (cmol kg^{-1}) levels had moderate to high variability. Results demonstrate that the CEC (cmol kg^{-1}) values for the three soil horizon depths of 0-50, 50-97 and 98-120 cm for the Eke market dump site were 16.0, 17.6 and 17.6, respectively (Table 3). As opposed to this, the horizon depth of the soils at the non-dump site ranged from 0-35, 35-69 and 69-120 cm, with respective CEC (cmol kg^{-1}) values of 12.4, 16.4 and 12.8 (cmol kg^{-1}). Three soil horizon depths of 0-54, 54-88 cm and 88-120 cm were found at the Abakpa Bridge Head Dump Site, with CEC (cmol kg^{-1}) values of 24.4, 14.8 and 15.6 (cmol kg^{-1}), respectively. The non-dump site soils, in comparison, had horizon 4 depths viz. 0-30, 30-59, 59-103 and 103-120 cm, respectively, with available CEC (cmol kg^{-1}) concentrations of 14.8, 14.8, 10.0 and 8.0 (cmol kg^{-1}). Comparatively, the soil CEC (cmol kg^{-1}) content was higher in the top 120 cm in the dumpsite soils compared to the non-dumpsite soils for both soils. According to a study conducted by Oorts *et al.*[28], SOC can account for as much as 76% of the variation in CEC and both SOC and pH can explain as much as 95% of the variation in CEC. Variation in CEC can be explained by soil organic matter and specific surface area (97%) and clay concentration (58%)[29]. The CEC stratification was seen in sites that were not waste dump sites. The high cation exchange capacities at the dumps resulted from the breakdown of urban waste, leading to increased fertility and production.

Base saturation measures the percentage of the cations on the soil colloid. The percent base saturation levels were characterized by relatively low to medium variability. Results show that the three soil horizon depths of 0-50, 50-97 and 98-120 cm of the Eke market dump site had percent base saturation values of 46.8, 27.7 and 29.9, respectively (Table 3). In contrast, the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm, with percent base saturation of 11.9, 10.2 and 13%, respectively. At the Abakpa Bridge Head

Dump Site, three soil horizon depths of 0-54, 54-88 and 88-120 cm had percent base saturation values of 37.5, 27.6 and 32.7%, respectively. In contrast, the horizon depths of the non-dump site soils were 4 and ranged from 0-30, 30-59, 59-103 and 103-120 cm, with percent base saturation of 19.2, 22.1, 22.8 and 36.0%, respectively. On average, the dump site soils had between 34-66% higher PBS than the non-dump soils for both study sites. The increased release of sodium, potassium, calcium and magnesium due to the decomposition of municipal wastes led to a larger percentage of base saturation at the dump sites. The percentage of base saturation in the soils at the dump site is higher than in the soils at non-dump site locations and this indicates that the soils at the dump site contain more exchangeable cations, which is a positive indicator of soil productivity.

Exchangeable cations (Ca, Mg, Na and K) content of Technosols in Dumpsites of Enugu urban: The Na (cmol kg^{-1}) levels were characterized by relatively medium to large variability. Results show that the three soil horizon depths of 0-50, 50-97 and 98-120 cm identified for the Eke market dump site had Na (cmol kg^{-1}) values of 0.13, 0.02 and 0.02, respectively (Table 4). In contrast, the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm, with Na (cmol kg^{-1}) of 0.02, 0.02 and 0.02, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54, 54-88 and 88-120 cm were identified with Na (cmol kg^{-1}) values of 0.06, 0.02 and 0.03 %, respectively. In contrast, the horizon depths of the non-dump site soils were 4 and ranged from 0-30, 30-59, 59-103 and 103-120 cm with Na (cmol kg^{-1}) contents of 0.01, 0.02, 0.02 and 0.02, respectively. The K^+ (cmol kg^{-1}) levels were characterized by relatively medium to large variability. Results showed that the three soil horizon depths of 0-50, 50-97 and 98-120 cm identified for the Eke market dump site had K^+ (cmol kg^{-1}) values of 0.16, 0.05 and 0.05, respectively (Table 4). In contrast, the horizon depths of the dump site soils ranged from 0-35, 35-69 and 69-120 cm, with K^+ (cmol kg^{-1}) of 0.06, 0.06 and 0.05, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54, 54-88 and 88-120 cm were identified with K^+ (cmol kg^{-1}) values of 0.10, 0.06 and 0.07%, respectively. In contrast, the horizon depths of the non-dump site soils were 4 and ranged from 0-30, 30-59, 59-103 and 103-120 cm with K^+ (cmol kg^{-1}) contents of 0.03, 0.05, 0.06 and 0.06, respectively. The Ca (cmol kg^{-1}) levels were characterized by relatively medium to large variability. Results showed that the three soil horizon depths of 0-50, 50-97 and 98-120 cm identified for the Eke market dump site had Ca (cmol kg^{-1}) values of 0.6, 0.6 and 1.6, respectively (Table 2). In contrast, the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm, with Ca (cmol kg^{-1}) of 1.0, 1.0 and 1.0, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54, 54-88 and 88-120 cm were identified with Ca (cmol kg^{-1}) values of 1.6, 0.6 and 0.4, respectively. In contrast, the horizon depths of the non-dump site soils were 4 and ranged from 0-30, 30-59, 59-103 and 103-120 cm with Ca (cmol kg^{-1}) contents of 1.0, 0.6, 0.6 and 1.0, respectively. The Mg^{2+} (cmol kg^{-1}) levels were characterized by relatively medium to large variability. Results show that the three soil horizon depths of 0-50, 50-97 and 98-120 cm identified for the Eke market dump site had Mg^{2+} (cmol kg^{-1}) values of 6.6, 4.2 and 3.6, respectively (Table 4). In contrast, the horizon depth of the dump site soils ranged from 0-35, 35-69 and 69-120 cm, with Mg^{2+} (cmol kg^{-1}) of 0.4, 0.6 and 0.6, respectively. At the Abakpa Bridge Head Dump Site, three soil horizon depths of 0-54, 54-88 and 88-120 cm were identified with Mg^{2+} (cmol kg^{-1}) values of 7.4, 3.4 and 4.6, respectively. In contrast, the horizon depths of the non-dump site soils were 4 and ranged from 0-30, 30-59, 59-103 and 103-120 cm with Mg^{2+} (cmol kg^{-1}) contents of 1.8, 2.6, 1.6 and 1.8, respectively.

The values of exchangeable cations (Na, K, Ca and Mg) in the dump and non-dump soils differed due to the soil's inherent qualities obtained from the local parent material. Akamigbo and Asadu[30] established that the parent material from which soil is generated controls the exchangeable cation and acidity of the soil. The significant precipitation typical of this region may have contributed to some degree of leaching, which is likely responsible for the low CEC.

Implication: The physicochemical properties of Technosols in dumpsites of Enugu, urban Southeastern Nigeria, indicate the potential environmental hazards and health risks associated with improper waste management practices in the area. The study highlights the need for sustainable waste management practices to protect the environment and public health in Enugu and other urban areas in Nigeria. The study's findings can be used to inform policymakers and stakeholders in the waste management sector about the need to regulate and monitor activities in dumpsites to reduce environmental and health risks.

Application: The study provides baseline data on the physicochemical properties of dumpsite Technosols and can be used to model future changes in these soils due to weathering or other factors. The information can be used to identify the potential sources of pollution in the dumpsites and to plan remediation strategies, such as bio-remediation. The study results can be used to develop guidelines for establishing and managing dumpsites in Enugu and other urban areas in Nigeria.

Recommendations: The study highlights the need for proper waste management practices, such as separating recyclable materials, composting and waste reduction techniques. There is a need for stringent monitoring and regulation of activities in dumpsites to minimize the risk of environmental and health hazards associated with waste disposal practices. More research is needed to investigate the long-term effects of dumpsites on the soil and their potential impact on the ecosystem.

Limitations: The study focused on Technosols in dumpsites within Enugu urban Southeastern Nigeria and the findings may not be generalizable to other regions or countries. The study did not investigate the impact of dumpsites on air and water quality, which is also a significant environmental hazard. The study did not investigate the effects of different types of waste on the physicochemical properties of soil in dumpsites.

CONCLUSION

In summary, the physicochemical properties of Technosols in Enugu Southeast Nigeria were affected by municipal waste disposal, resulting in slight changes in their pedogenesis. However, they have the potential to positively impact agricultural soil quality in tropical environmental conditions. It is recommended that proper waste treatment, control and monitoring strategies be implemented to mitigate negative impacts on soil quality. Additionally, future studies should focus on long-term effects and ways to promote the sustainable use of waste-derived Technosols for agricultural purposes.

SIGNIFICANCE STATEMENT

This study examined the effects of municipal waste dumping on Technosols in Enugu, Nigeria and compared their properties to natural soils. The researchers investigated pH levels, organic matter content, CEC, total nitrogen and macro and micro-nutrients. The findings will be useful in identifying quality monitoring indicators for sustainable green city development. While the study found slight changes in pedogenesis, it also revealed the potential for Technosols to positively impact agricultural soil quality in tropical environmental conditions. However, proper waste treatment and monitoring strategies are necessary to mitigate adverse impacts on soil quality. Future research should focus on the long-term effects of Technosols. This includes investigating the impact on the surrounding environment, microbial diversity, contaminants distribution, land-use applications, as well as local communities social and economic impacts.

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