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Assessment of Heavy Metal Concentrations in Domestic Waste Dump Soil Samples Obtained within Kaduna Metropolis in Relation to Seasonal Variations

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Abstract

This study investigated the effects of domestic waste dumpsite soil during wet and dry seasons of 2024 in Kaduna Metropolis, Nigeria. Soil samples were collected from nine dumpsites and one control were analyzed for heavy metal concentrations (Pb, Cr, Cd, Ni, Hg) using Atomic Absorption Spectrophotometer (AAS). The data collected was subjected to analysis of variance using statistical analysis software (SAS) version 9.0 and all the results revealed statistically significant differences ($p<0.05$). Heavy metal concentrations in soil during wet season recorded the highest values of Pb (725.10)> Ni (70.30)>Cr (51.47)> Hg (44.13)>Cd (34.45 mg/kg) respectively. There was general decrease in mean concentration of total values of the heavy metals during dry season except Cr and Hg that had an increased values when compared with wet season Pb (334.8)> Cr (224.7)> Hg (51.6)> Ni (33.4)> Cd (18.9 mg/kg) respectively. All the total mean concentrations in both seasons were above the permissible limit for EU and WHO standards in several locations. The control had the least concentration of all the selected metals. The study concludes that domestic waste dumping substantially alters soil chemical properties, increasing heavy metal accumulation beyond safe limits. It is therefore recommended that wastes management and remediation strategies should be impose because they are essential for reduction of heavy metal contamination in soil and provide environmental protection and human health.

Keywords: Assessment, Heavy metals, Dumpsites, Soil, Kaduna, Metropolis, Seasonal variations.

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Introduction

Soil is the primary medium for plant nutrition, serving as a natural reservoir for nutrients while also acting as a sink for pollutants, influencing groundwater and air quality [5]. Natural soils significantly differ from those affected by anthropogenic activities, particularly in areas contaminated by waste deposits, which are often unsuitable for plant growth. The increasing generation of domestic waste and its indiscriminate disposal have led to severe environmental concerns, particularly in developing countries where waste management infrastructure is inadequate [2].

Dumpsites serve as designated locations for waste disposal and management to prevent environmental pollution caused by indiscriminate refuse dumping, landfills and dumpsites are major sources of metal pollutants and other hazardous materials that accumulate in the soil, potentially affecting plant growth and soil quality [3]. Nigeria, with a population exceeding 170 million, generates approximately 32 million tons of solid waste annually, much of which originates from residential and industrial activities [1]. These wastes, when deposited at dumpsites, undergo physicochemical and biological transformations, releasing varying concentrations of heavy metals that are detrimental to surrounding organisms and the ecosystem [4].

Soil is one of the major recipients of heavy metals released via leachates from dumpsites. Heavy metals alters soil physical, chemical and biological properties, posing a serious concern to sustainable agricultural practices [11]. Heavy metals such as Sn, Cu, Ni, Cd, Zn, Cr and Pb are considered major sources of soil pollution which is caused by various metals [14]. Some heavy metals (like Fe, Zn, Ca and Mg) have been reported to be of bio-importance to man and their daily medicinal and dietary allowances had been recommended [7]. However, some others (like Cr, Cd, Pb, and methylated forms of Hg) have been reported to have no known bio-importance in human biochemistry, physiology and consumption even at very low concentrations can be toxic [9].

The exposure to heavy metals can cause serious health issues such as cancer, skin defects, birth defects, impairments in functions of the kidney, nervous system, gastrointestinal tract, circulatory system, immune system, vascular system and apoptosis [10]. The toxicity of the environments by the non-essential heavy metals cannot be overemphasized, several reports have been documented on varying concentrations levels of heavy metals in soil around dumpsites in Nigeria and other African countries [11]

The aim of the study was to assess the concentrations of heavy metals in domestic waste dumpsite soils

Materials and Methods

Study Location

The research was conducted in the Biological Garden Kaduna State University, Bio Chemistry laboratory Kaduna State University. It covers land area of about 10.31^0 Latitude, and 7.26^0 Longitude and 6.14 meters elevation above sea level, the postal code of the area is 800. The climate of the study location is characterized by two seasons; wet and dry season, the soil is mainly sandy clay. National soil and Fertilizer Development Centre (NFDC) Federal Ministry of Agriculture and Rural Development Goningora Abuja Road Kaduna. The sampling site cut across one control and nine locations within three local government area in Kaduna State metropolis namely; Mando, Barakallahu and Rigasa of Igabi, Ungwan Rimi, Kawo and Ungwan Shanu of Kaduna North, Ungwan Sunusi, Tudun Wada and Kakuri of Kaduna South.

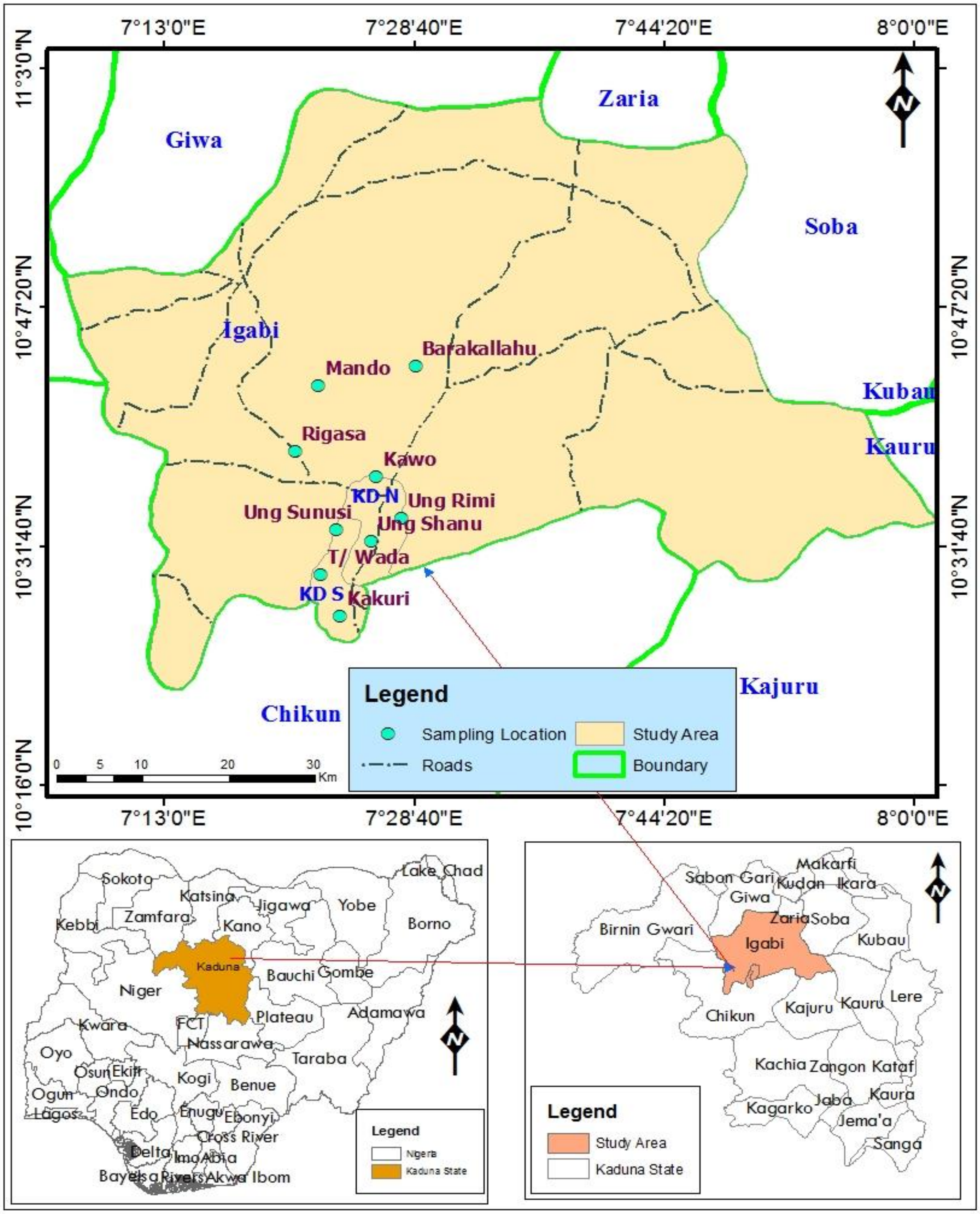

Figure 1: *A Map of the Study Area Showing Sampling Location.*

Source: *Kaduna State University GIS Laboratory.*

Soil Sample Collection

Samples of domestic wastes dump soil were collected from nine different dumpsites, three sample from each Local Government Area. (site A) Mando, Barakallahu and Rigasa of Igabi, (site B) Ungwan Rimi, Kawo and Ungwan Shanu of Kaduna North, (site C) Ungwan Sunusi, Tudun Wada and Kakuri of Kaduna South due to their population which leads to high rate of soil nutrients, soil contamination with heavy metals and other contaminants. Nine samples from the above locations were collected and one control sample making ten total samples from a depth of 0–35 cm deep and 50cm apart using a stainless-steel shovel in August 2024 and in January 2025. Visible roots, stones and organic residue was manually removed.

The collected composite soil samples were thoroughly mixed in plastic bucket and then transferred into a large sacs and were all taken to biological garden Kaduna state university where planting took place, the soil samples were further crushed and sieved with 2mm mesh, 50g each of the soil samples were collected and stored in sterile polythene bags [2] samples were taking to laboratory for heavy metals. The location of the sample sites was determined with the aid of a Global Positioning System (GPS) method adopted by [6].

Samples Analysis

Preparation of Soil Samples

All collected soil samples from each zone of the study sites was air-dried at room temperature of 20C, crushed, and sieved to remove larger particles and debris and make the samples smooth through a 2 mm mesh before they were subjected for heavy metal analysis [2].

Digestion of Soil Samples

One gram of the soil sample was weighed into a digestion vessel and mix with acids, 25ml of Aqua regia (18.75ml of HCL and 6.25ml of HNO_3).

Mixture in a digestion apparatus was heated on electric hot plate for 40 minutes under 80^0C until a clean solution was obtained, distilled water was added to make it up to 50ml of the total digested sample in 50ml volumetric flasks the digested solution was left to cool and then filter through a whatman No. 42 filter paper to remove any remaining solid particles [13].

Heavy Metal Determination

Digested soil solutions were introduced into **Atomic Absorption Spectrophotometer (AAS).** The absorbance of each metal at its characteristic wavelength (about 217 nm) was recorded for each selected metal. calibration curves to determine the amount and total concentration of each metal in the samples was used. proper disposal procedures for chemical wastes and contaminated materials and quality control was implemented (Mirosławski & Paukszto, 2018).

Data Analysis

The data obtained from the soil and plant samples were subjected to Analysis of Variance (ANOVA) using Statistical Analysis Software (SAS) version 9.0 was used to determine the significant difference of heavy metals concentration in soil and also T-Test was used to compare the seasonal variation of the selected heavy metals in soil.

Results

Concentration of Heavy Metal in Soils During Wet and Dry Season

Concentrations of heavy metals of 10 domestic waste dump soil samples in wet and dry Seasons within Kaduna metropolis in wet season, lead concentrations in soil samples varied significantly across locations ($p < 0.05$). Rigasa recorded the highest concentration of 725.10 and Kawo with 680.40, followed by Tudun Wada, Mando, Ungwan Shanu, Kakuri, Ungwan Sunusi, Barakallahu, Ungwan Rimi and control with 149.15, 135.42, 134.67, 120.05, 211.65, 109.05, 69.70 and 50.95 mg/kg, respectively, while soil sample from Kawo had the least concentrations of 29.20 mg/kg (Table 1). During dry season, lead concentrations in soil samples varied significantly across locations ($p < 0.05$). Barakallahu recorded the highest concentration at 334.8 mg/kg, followed by Mando at 38.1 and Ungwan Sunusi at 35.4. Rigasa and Kakuri had concentrations of 28.3 and 25.0, while Ungwan Shanu and Ungwan Rimi soils had lead concentrations of 25.1 and 20.4 mg/kg, respectively. Tudun Wada 2.81, and Kawo had a minimal concentration of 0.27 and the control plot had no detectable lead (0.00) (Table 1).

Chromium (Cr) content: The pre-planting concentrations of chromium in the wet season differed significantly ($p < 0.05$) in soil samples from the different sampling locations (p < 0.05). Soil sample from Kawo had the highest chromium content (51.47) followed Kakuri, Ungwan Shanu, control, Ungwan Sunusi, Rigasa and Mando, with chromium concentrations of 49.15, 46.86, 45.50, 43.39, 39.23 and 31.90. Barakallahu and Ungwan Rimi were 30.29 and 24.85 mg/kg, respectively, while the least chromium contents are in soils from control with 21.95. (Table 1). Pre-planting chromium concentrations varied significantly (p < 0.05), with Ungwan Rimi recording the highest at 224.7 mg/kg, followed by Mando at 143.3. Ungwan Shanu and Barakallahu had 115.4 and 109.6, respectively, while Rigasa and Ungwan Sunusi recorded 109.0 and 97.8, Kakuri, Tudun Wada, Kawo, and control had lower concentrations at 93.3, 82.7, 81.3, and 78.0 mg/kg, respectively (Table 1).

Cadmium (Cd) content: Cadmium concentrations showed significant variation ($p < 0.05$) between sampling plant. The soil from Rigasa, Barakallahu and Ungwan Sunusi recorded the highest concentration of cadmium at 34.45, 14.50 and 14.45, followed by Kawo, Ungwan Shanu, Ungwan Rimi, Tudun Wada, Kakuri, and the control with concentrations of 13.35, 13.30, 11.77, 11.60, 10.45 and 6.70 mg/kg, respectively. Soil samples from Mando had the lowest concentration of cadmium (3.50) (Table 1). Cadmium concentrations before planting during dry season differed significantly ($p < 0.05$), with Mando recording the highest at 18.9 mg/kg, followed by Ungwan Shanu and Ungwan Rimi at 8.16 and 8.07 mg/kg, respectively. Ungwan Sunusi, Kawo, and Barakallahu 7.10, 7.06, and 6.86, while Kakuri recorded 6.46. Tudun Wada 3.88 and control had the lowest value of 1.25 mg/kg, respectively (Table 1).

Nickel (Ni) content: The soil concentrations of Nickel in wet season varied significantly across locations ($p < 0.05$). The Soils from Kawo had the highest concentration of nickel 70.30, followed by Ungwan Sunusi, Rigasa and Ungwan Shanu (40.05), (36.34) and (32.54), Ungwan Rimi (23.93) Kakuri (21.05), Barakallahu (20.80), Rigasa (18.50), Mando (17.40) and Tudu wada (17.29). While the control sample had the lowest concentration of nickel (6.65 mg/kg) (Table 4.2). In dry season, pre-planting nickel concentrations varied significantly ($p < 0.05$), with Ungwan Rimi recording the highest at 33.4 mg/kg, followed by Ungwan Sunusi (31.8) and Mando (30.3). Rigasa, Barakallahu, and Ungwan Shanu had concentrations of 29.9, 27.7, and 27.3. Kawo and Kakuri recorded 25.0 and 24.7 mg/kg, respectively, while Tudun Wada and the control had lower concentrations at 19.7 and 16.5 mg/kg, respectively (Table 1).

Mercury (Hg) content: Concentrations of mercury differed significantly ($p < 0.05$) between wet and dry season. Soil sample from Kakuri recorded the highest concentration of mercury at 44.1, followed by Barakallahu (27.30), Rigasa (22.5), Mando (18.75), Kawo (9.70) Ungwan Sunusi (7.05), Tudun Wada (6.65) and Ungwan Rimi has the lowest concentration of mercury (5.35), respectively. In samples from the control and Ungwan Shanu, the concentrations of mercury at 1.30 and 0.35 mg/kg, respectively. (Table 1). In dry season, Ungwan Sunusi recorded highest at 51.6, followed by Kakuri at 35.4 and Ungwan Shanu at 34.1, Tudun Wada and Ungwan Rimi had 33.6 and 22.0, Kawo and Mando recorded 25.6 and 21.8. Rigasa had 18.1, Barakallahu and control had the lowest concentrations at 3.73 and 0.63 mg/kg, respectively (Table 1).

Table 1 Concentrations of Heavy Metals of 10 Domestic Waste Dump Soils Samples in Wet and Dry Seasons within Kaduna Metropolis

Location	Wet Season					Dry Season				
	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Hg (mg/kg)	Pb (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Hg (mg/kg)
Mando	135.42 ± 0.33^{c}	31.90 ± 0.10^{b}	6.70 ± 0.10^{b}	17.40 ± 0.30^{g}	18.75 ± 0.02^{b}	38.1 ± 0.58^{b}	143.3 ± 0.58^{b}	18.9 ± 0.10^{a}	30.3 ± 0.58^{c}	21.8 ± 0.13^{f}
Barakallahu	109.05 ± 0.03^{b}	30.29 ± 0.44^{f}	14.50 ± 0.09^{a}	20.80 ± 0.10^{e}	27.30 ± 0.20^{a}	334.8 ± 0.20^{a}	109.6 ± 0.08^{d}	6.86 ± 0.01^{e}	27.7 ± 0.20^{d}	3.73 ± 0.21^{h}
Rigasa	725.10 ± 0.10^{a}	39.23 ± 0.15^{a}	34.45 ± 0.06^{a}	36.34 ± 0.04^{c}	22.45 ± 0.02^{c}	28.3 ± 0.15^{d}	109.0 ± 0.15^{c}	12.0 ± 0.10^{b}	29.9 ± 0.24^{c}	18.1 ± 0.14^{g}
U/Rimi	69.70 ± 0.20^{i}	24.85 ± 0.03^{h}	11.77 ± 0.15^{b}	23.93 ± 0.15^{e}	5.35 ± 0.03^{e}	20.4 ± 0.03^{f}	224.7 ± 0.03^{a}	8.07 ± 0.02^{c}	33.4 ± 0.06^{a}	22.0 ± 0.19^{f}
Kawo	680.40 ± 0.10^{b}	51.47 ± 0.10^{j}	13.35 ± 0.04^{b}	70.30 ± 0.20^{a}	9.70 ± 0.20^{d}	0.27 ± 0.02^{h}	81.3 ± 0.15^{i}	7.06 ± 0.02^{d}	25.0 ± 0.10^{e}	25.6 ± 0.07^{c}
U /Shanu	134.67 ± 0.15^{d}	46.86 ± 0.07^{b}	13.30 ± 0.20^{b}	32.54 ± 0.12^{d}	0.35 ± 0.02^{h}	25.1 ± 0.43^{e}	115.4 ± 0.43^{c}	8.16 ± 0.02^{c}	27.3 ± 0.12^{d}	34.1 ± 0.06^{c}
U/Sunusi	149.15 ± 0.04^{d}	45.50 ± 0.40^{c}	10.45 ± 0.03^{e}	17.29 ± 0.44^{cd}	6.65 ± 0.01^{d}	35.4 ± 0.12^{c}	97.8 ± 0.07^{f}	7.10 ± 0.10^{d}	31.8 ± 0.15^{b}	51.6 ± 0.10^{a}
T/Wada	211.65 ± 0.04^{b}	43.39 ± 0.45^{b}	14.45 ± 0.01^{a}	40.05 ± 0.03^{b}	7.05 ± 0.04^{e}	2.81 ± 0.24^{g}	82.7 ± 0.26^{h}	3.88 ± 0.14^{g}	19.7 ± 0.25^{f}	33.6 ± 0.02^{d}
Kakuri	120.05 ± 0.02^{e}	49.15 ± 0.03^{a}	11.60 ± 0.20^{c}	21.05 ± 0.02^{f}	44.13 ± 0.15^{a}	25.0 ± 0.15^{e}	93.3 ± 0.02^{g}	6.46 ± 0.01^{f}	24.7 ± 0.20^{e}	35.4 ± 0.30^{b}
Control	50.95 ± 0.04^{j}	21.95 ± 0.02^{i}	3.50 ± 0.40^{g}	6.65 ± 0.01^{i}	1.30 ± 0.20^{h}	0.00 ± 0.00^{i}	78.0 ± 0.15^{j}	1.25 ± 0.01^{h}	16.5 ± 0.02^{g}	0.63 ± 0.06^{i}
EU (2023)	100-300	150-300	0.5-1.0	50-100	1.0	100-300	150-300	0.5-1.0	50-100	1.0

Values are expressed as means ± standard deviation. Means values at each column followed by different superscripts are considered to be significantly different at $p < 0.05$.

Discussion

The high concentration of Lead Pb in Rigasa during wet season and Barakallahu during dry season was as a result of improper disposal of metal scraps, burning of E-waste (Electronic wastes) such as lead acid batteries from vehicles, paint wastes and broken objects contribute lead residues to the dumpsites which eventually accumulate and may become difficult to control. This is agreed with the result obtained by Ojiego et al. (2022). Who worked on concentration of heavy metals in soil samples from dumpsites located at Kuje and Kwali area council Abuja, Nigeria. And reported that lead concentration in dump soil is usually above the permissible limit stipulated by NESREA for Nigerian soil.

The seasonal variation is the changes in physical, chemical and biological characteristics of the environment across different times of the year which is mainly influenced by distinct Nigerian wet and dry season. Therefore, seasonal variation of the selected heavy metal concentrations in the domestic waste dump soil during wet and dry season revealed that Cd, Cr, Ni, and Hg showed highly significant difference between wet and dry while Pb concentration indicated that there is no significant difference between both seasons. This is agreed by (Mohammad et al., 2025) who worked on Assessment of heavy metal concentration and soil physicochemical properties from major dumpsites around active abattoirs in Kaduna metropolis. He stated that base on the extremely concentration of lead in soil from wet and dry season, contaminated soil is therefore unfit to use in cultivating crops.

Conclusion

There was high concentration of Pb that yielded 725mg/kg and Hg was the least concentration that yielded 0.35mg/kg in the soil during wet season. While in the dry season, there was also high concentration of Pb with the value 334.8mg/kg and the least concentration was recorded in Hg with value 0.63mg/kg in the soil during dry season.

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