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Seasonal Variation of Contamination of Heavy Metals in Soils of Selected Refuse Dumpsites in Lafia Metropolis, Nigeria

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ABSTRACT

Dumpsite is considered as one of the major sources of heavy metal pollution. Arising from population explosion and commercial activities, tons of solid wastes are generated and disposed daily in open dumps of most Nigerian cities. This has led to contamination of the environment, which impacts negatively on human health. In this study, concentrations of heavy metals of 19 soil samples, from randomly selected refuse dumpsites in Lafia metropolis, Nigeria, were evaluated using Atomic Absorption Spectroscopy and Association of Official Analytical Chemists (AOAC) standard methods. The results showed that during the wet season, the mean concentration of heavy metals were 0.000-0.332 (Hg), 0.197-1.240 (Cr), and 0.528-1.173 (Mn) mg/kg, and above the maximum permissible limits by World Health Organisation (WHO), and the National Environmental Standards and Regulations Enforcement Agency (NESREA), while that of Pb, As, Fe, Zn, Cu and Ni were below the tolerable limits. In the dry season, the levels of Hg (0.000-0.234), Cr (0.117-1.667), and Mn (0.390-2.318) mg/kg across the locations were above the tolerable limits. The study recommends that government agencies should integrate regular monitoring of waste disposal into the state developmental plan and framework to prevent excessive build-up of these metals in humans through the food chain.

Key Words: Heavy metal pollution, Refuse dumpsites, Solid waste

INTRODUCTION

All wastes have the potential to cause environmental damage. One of the recent global challenges facing towns and cities is solid waste management. The pressure of population growth causes environmental degradation and in particular solid waste thereby polluting air, water and land on which all life so critically depends on [1,2]. Going by the resource and energy demand on the environment and the internal pollution by man through inhalation and ingestion of alien chemical substances, man is best described as a chemical factory in terms of material use and waste [3].

The impact of solid waste on health and environment has been an issue of global concern over the years. Solid wastes are sources of environmental pollution through introduction of chemical substances above their threshold limit into the environment. Soil is a natural reservoir of metals whose concentrations are associated with several factors such as biological and biogeochemical cycling, parent material and mineralogy, soil age, organic matter, soil pH, redox concentrations and microbial activities. The amount and variety of waste materials have drastically increased with the growth of technology and population [4].

The municipal solid wastes (MSW), often referred to as “Garbage or Trash” are undesirable materials mainly consisting of household wastes such as papers, metal scraps, glasses, batteries, electronic appliances, plastics and motor oil. These materials release different elements into the soil through decomposition or oxidation [5]. Waste management is a major challenge for cities in developing countries, owing to the increasing stream of waste generated, driven by population growth, industrialization and urbanization [6, 7].

The most common pollutants found in refuse dumps are heavy metals. These metals are released into the environment from natural, agricultural, industrial and other anthropogenic sources. The heavy metals intrude into the environmental matrices through several processes like industrial practices, agricultural activities, energy consumption, domestic wastes and vehicular emissions [8].

Heavy metals are those metals with specific gravity higher than 5 g/cm^3 [9, 10]. They are stable elements that cannot be metabolized and are not biodegradable [11]. They are typically classified into two major forms including essential and non-essential metals. Essential heavy metals have beneficial role in living things at certain concentrations. Some of these heavy metals include Fe, Mn, Cu, Zn and Cr. High concentration of essential metals in biological system could lead to toxicity to the exposed organisms. Others such as lead, cadmium, mercury and arsenic have no known role in living organisms and as such, they are highly lethal even at low concentration [12-13].

Lafia, the capital city of Nasarawa State in North Central Nigeria, is faced with waste disposal problems in residential areas and other public places. It is a common practice to find huge dumpsites within residential areas along major and minor roads. Lafia is experiencing problems of municipal solid waste management principally as a result of unplanned development, rural-urban migration and natural population growth within the city. This growth rate has not been matched by much improvement in the quality of urban environmental waste management. Instead, these demographic expansion, and commercial activities have caused increase in the volume and diversity of solid waste generated in the city [14].

The aim of the study is to determine the concentrations of heavy metals, Pb, Hg, As, Cr, Fe, Zn, Cu, Mn, Ni, B in soil samples at waste dumpsites in Kwandare, Millionaires' Quarters, Tudun Amba, Gandu and Tudun Abu locations of Lafia Metropolis, Nigeria.

Description of the Study Area

The study area is Lafia Local Government Area with about fifty neighborhoods. Lafia is the capital of Nasarawa State which is located in the middle belt region of Nigeria. The state lies between longitude 7^{o} and 9^{o} 37'E of the Greenwich Meridian and has an altitude of 600 m above sea level [15-16]. Lafia town is the headquarters of Lafia Local Government which is the third largest in the state with a land area of 2,797 sq. km. Nasarawa (5,743 sq. km), Awe (2,800 sq. km), and Karu (2,710 sq. km) are the first, second, and third largest Local Governments in that order. The population of Lafia Local Government Area by 2006 National Population Census is 330,712. The study has further projected the population to 563,004 by 2024, at a growth rate of 3.0% [17, 18].

Nasarawa State lies to the East of the Federal Capital Territory (FCT) Abuja. Lafia town is the state's close settled cell with intensive land use in a corridor of development. That is, the urban development of Lafia is most intense by the standard of the Northern and Middle belts of Nigeria. With the creation of the Federal Capital Territory (FCT), the development corridor is pushing westward from Lafia joining Nyanya, Karu, southward from Lafia towards Agyaragu and Makurdi [19].

The mean monthly temperature in the Lafia area ranges between 36 ^{o}C in March and 30 ^{o}C in December [20]. This is a very close range and at such high level, the hot weather is a regular feature of the Lafia area. The discomfort becomes greater with the rising humidity in March-April before the cooling effect of the rains. The mean annual rainfall of 270-1530 mm is mainly received for seven months (April to October) of the rainy season. That is, the area has just about 5 months of dry season (November-March). Lafia area is within the Southern Guinea Savannah vegetation belt. The rainfall and other environmental factors support the natural vegetation consisting of open forest dominated by trees and tall grasses, the establishment of orange and cashew orchards and forest reserves. Seasonally, cultivated areas have become altered into sub-Sudan vegetation with more scattered trees and shrubs as well as grasses [17].

MATERIALS AND METHODS

Reagents

The chemicals and reagents used in this study were: chromic acid, potassium permanganate, hydrochloric acid, nitric acid, silver chromate, potassium dichromate, concentrated sulphuric acid, ferrous ammonium sulphate, calcium chloride, and potassium chloride. All were of Analytical Grade, while distilled water was used for the preparation of solution.

Equipment and instruments

The equipment and instruments used in the study were: Analytical balance, centrifuge, reflux condenser, spectrophotometer (SP-VG722), Atomic absorption spectrophotometer (AA320N), oven, fume cupboard, thermometer, pH meter, conductivity meter, and Global positioning system (GPS).

Sample collection

Soil samples were collected at 0-15 cm below the topsoil with the aid of soil Auger, from thirty-eight (38) refuse dumpsites and twelve (12) control sites across the Lafia metropolis and environs; North, South, East, West and Central (Table 1) in wet season (September 2021) and dry season (March 2022). The control samples were obtained at various locations away from different refuse dumpsites. The sampling units cut across twelve major locations namely: Kwandare, Millionaires quarters, Tudun Amba, Gandu and Tudun Abu.

Table 1: Geographical locations of sampling sites

S/N	Location	Sites	No. of samples collected	
			Wet	Dry
1	Northern part of Lafia Metropolis	Kwandare	5	5
2	Central part of Lafia Metropolis	Millionaires Quarters	5	5
4	Southern part of Lafia Metropolis	Gandu	3	3
5	Eastern part of Lafia Metropolis	Tudun Abu	3	3
		Total	19	19

Sampling design

Each sampling unit from the refuse dumpsites was 50 m, 100 m apart and the control was taken far away from the refuse dumpsites. The sampling technique was stratified random sampling [21-22]. Composite of individual units of three samples were taken from each dumpsites [23-26].

Sample preparation

Composite samples made by mixing individual sample units were transferred into a polythene bag, tightly sealed to prevent breakdown of organic matter and transported for analysis. The samples were air dried for 48 hours, ground to pass through a 2 mm sieve to remove debris, gravel and other materials. Samples at 50 m, 100 m from each refuse dumpsites and control sites free from dumpsites were determined. Results obtained were expressed as mean ± standard deviation of the measurements.

Global Positioning System: Coordinates and Elevation of the Sampling Sites

The geographical coordinates of the sampling points were obtained using Global Positioning System meter (GPS ETREX Garmin) (Table 2) [27-28].

Table 2: Geographical Positions of the Soil Samples from Refuse Dumpsites in

(1) Kwandare

Dumpsites		Northing	Easting	Altitude (m)
1	Primary Health Care	444940	946861	145
2	Primary Health Care	444928	946857	144
3	Ombi Anzaku	445158	944572	136
4	Ombi Anzaku	445149	944602	137
5	Ctrl	445624	945909	160

(2) **Millionaires Quarters**

6	MIMA Hospital	446860	941839	181
7	MIMA Hospital	446855	941836	182
8	Transformer Street	446843	941826	172
9	Transformer Street	446558	941746	172
10	Ctrl	446552	941750	173

(3) **Tudun Amba**

11	DOMA Road	446778	938965	182
12	DOMA Road	446772	938964	187
13	Ctrl	443876	937640	160

(4) **Gandu (Telecomm. Masts (Students' village)**

14	Telecomm Mast	452532	937578	178
15	Telecomm Mast	452525	937577	178
16	Ctrl	452566	937570	177

(5) **Tudun Abu (Shendam Road)**

17	Shendam Road (Tudun Abu)	451480	941038	202
18	Shendam Road (Tudun Abu)	451474	941045	201
19	Ctrl	450470	941050	202

Digestion of Samples and Analysis of Heavy metals

Approximately 2 g of the sieved soil samples were digested for 3 hours at 85 ^{o}C in 12 mL of aqua regia (3:1 HCl-HNO_3 v/v) using hot plate in a fume cupboard until white fumes were observed. The sample was cooled to room temperature and then diluted with 20 mL of distilled water. The mixture was filtered to complete the digestion. The extracts (digested soil waste samples) were analyzed for the heavy metals; Pb, Hg, As, Cr, Fe, Zn, Cu, Mn, Ni, B using AAS (AA320N, China) [7, 29].

RESULTS AND DISCUSSION

Concentration of metals in the soil samples collected from each dumpsite was evaluated, and the results are presented in Tables 3 -.7.

Table 3: Concentrations of Heavy Metals in Soil Samples from Refuse Dumpsites in Kwandare (Primary Health Care and Ombi Anzaku)

		Wet Season									
S/N	Sample Code	Pb (mg/kg)	Hg (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	B (mg/kg)
1	PHC1	0.320±0.001	0.184±0.001	0.740±0.001	0.677±0.001	0.406±0.001	0.361±0.001	0.781±0.001	0.741±0.001	0.506±0.001	0.424±0.001
2	PHC2	0.216±0.001	0.281±0.001	0.900±0.001	0.642±0.001	0.471±0.001	0.348±0.001	0.796±0.001	0.901±0.001	0.069±0.001	0.400±0.001
3	OA1	0.287±0.001	0.223±0.001	0.212±0.001	0.873±0.001	0.702±0.001	0.315±0.001	1.086±0.001	0.766±0.001	0.163±0.001	0.571±0.001
4	OA2	0.456±0.001	0.246±0.001	0.270±0.001	0.902±0.001	0.591±0.001	0.300±0.001	1.058±0.001	1.175±0.001	0.098±0.001	0.894±0.001
	$\bar{X}$	0.319±0.001	0.234±0.001	0.531±0.001	0.774±0.001	0.543±0.001	0.331±0.001	0.930±0.001	0.896±0.001	0.459±0.001	0.572±0.001
5	Ctrl	0.509±0.001	0.106±0.001	0.365±0.001	0.795±0.001	0.301±0.001	0.211±0.001	0.351±0.001	1.222±0.001	0.490±0.001	1.055±0.001
		Dry Season									
S/N	Sample Code	Pb (mg/kg)	Hg (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	B (mg/kg)
6	PHC1	0.001±0.001	0.081±0.001	0.797±0.001	1.167±0.001	0.506±0.001	2.879±0.001	0.672±0.001	0.424±0.001	0.312±0.001	0.324±0.001
7	PHC2	0.002±0.001	0.052±0.001	0.122±0.001	2.167±0.001	0.671±0.001	3.068±0.001	0.696±0.001	0.601±0.001	0.165±0.001	0.506±0.001
8	OA1	0.760±0.001	0.010±0.001	1.068±0.001	1.167±0.001	0.706±0.001	7.354±0.001	0.188±0.001	2.000±0.001	0.163±0.001	0.673±0.001
9	OA2	0.360±0.001	0.024±0.001	1.473±0.001	2.167±0.001	0.702±0.001	3.513±0.001	0.261±0.001	3.212±0.001	0.095±0.001	0.784±0.001
	$\bar{X}$	0.281±0.001	0.042±0.001	0.865±0.001	1.667±0.001	0.646±0.001	4.204±0.001	0.454±0.001	0.390±0.001	0.184±0.001	0.572±0.001
10	Ctrl	0.000±0.001	0.006±0.001	1.338±0.001	0.000±0.001	0.204±0.001	3.664±0.001	0.201±0.001	3.394±0.001	0.032±0.001	1.003±0.001
(WHO (mg/kg)		0.3-10	0.001-0.04	10	0.002-0.2	100-1000	12-60	1-12	0.1	0.1-5	NA
NESREA (mg/kg)		0.1	0.0005	0.05	NA	0.5	NA	0.01	NA	NA	NA

Values are mean± standard deviations (n=3).

Key: PHC= Primary Health Care; OA= Ombi Anzaku ; Ctrl= Control ; NA= Not Available

Table 4: Concentrations of Heavy Metals in Soil Samples from Refuse Dumpsites in Millionaires Quarters (MIMA Hospital and Transformer Street)

		Wet Season									
S/N	No	Pb (mg/kg)	Hg (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	B (mg/kg)
11	MIMAH1	0.381±0.084	0.226±0.058	0.467±0.072	0.671±0.078	0.599±0.073	0.066±0.072	0.544±0.104	0.357±0.091	0.566±0.075	0.212±0.069
12	MIMAH2	0.486±0.048	0.237±0.072	0.230±0.084	0.583±0.094	0.686±0.061	0.052±0.062	0.234±0.045	0.360±0.083	0.424±0.062	0.547±0.017
13	TSBE1	0.812±0.108	0.424±0.090	0.443±0.061	0.624±0.082	0.581±0.085	0.145±0.073	0.172±0.088	0.785±0.072	0.545±0.085	0.626±0.091
14	TSBE2	0.463±0.067	0.439±0.083	0.708±0.093	0.699±0.052	0.341±0.082	0.034±0.072	0.000±0.083	0.609±0.072	0.459±0.051	0.479±0.104
	$\overline{X}$	0.536±0.077	0.332±0.076	0.462±0.078	0.644±0.077	0.552±0.075	0.074±0.070	0.238±0.080	0.528±0.080	0.499±0.068	0.466±0.070
15	Ctrl	0.000±0.000	0.134±0.054	0.136±0.028	0.386±0.053	0.366±0.057	0.015±0.012	0.510±0.042	1.739±0.018	0.412±0.108	1.246±0.501
		Dry Season									
S/N	Sample Code	Pb (mg/kg)	Hg (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	B (mg/kg)
16	MIMAH1	0.260±0.084	0.150±0.058	0.382±0.072	0.367±0.078	0.601±0.073	4.516±0.072	0.261±0.104	2.182±0.091	0.478±0.075	0.112±0.069
17	MIMAH2	0.360±0.048	0.150±0.072	0.386±0.084	0.316±0.094	0.611±0.061	5.272±0.062	0.116±0.045	4.242±0.083	0.414±0.062	0.436±0.017
18	TSBE1	0.160±0.108	0.317±0.090	1.338±0.061	1.167±0.082	0.781±0.085	3.361±0.073	0.043±0.088	3.394±0.072	0.535±0.085	0.516±0.091
19	TSBE2	0.160±0.067	0.217±0.083	1.308±0.093	1.067±0.052	0.676±0.082	3.674±0.072	0.043±0.083	3.455±0.072	0.517±0.051	0.572±0.104
	$\overline{X}$	0.235±0.077	0.209±0.076	0.834±0.078	0.729±0.077	0.667±0.075	4.208±0.070	0.116±0.080	2.318±0.080	0.486±0.068	0.409±0.070
20	Ctrl	0.060±0.000	0.317±0.054	1.068±0.028	1.166±0.053	0.201±0.057	3.201±0.012	0.000±0.042	3.697±0.018	0.312±0.108	1.046±0.501
(WHO (mg/kg)		0.3-10	0.001-0.04	10	0.002-0.2	100-1000	12-60	1-12	0.1	0.1-5	NA
NESREA (mg/kg)		0.1	0.0005	0.05	NA	0.5	NA	0.01	NA	NA	NA

Values are mean± standard deviations (n=3).

Key: MIMAH= MIMA Hospital; TSBE= Transformer Street; Ctrl=Control; NA= Not Available

Table 5: Concentrations of Heavy Metals in Soil Samples from Refuse Dumpsites in Tudun Amba (Doma Road)

		Wet Season									
S/N	Sample Code	Pb (mg/kg)	Hg (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	B (mg/kg)
21	DR1	0.792±0.621	0.000±0.000	0.077±0.031	0.880±0.218	0.383±0.108	0.131±0.084	0.406±0.068	0.480±0.021	0.756±0.083	0.353±0.069
22	DR2	0.547±0.219	0.100±0.089	0.386±0.068	1.026±0.318	0.365±0.109	0.093±0.021	0.130±0.010	1.116±0.062	0.738±0.083	1.217±0.521
	$\overline{X}$	0.670±0.042	0.050±0.045	0.232±0.050	0.953±0.268	0.374±0.109	0.112±0.053	0.268±0.039	0.798±0.042	0.747±0.083	0.785±0.295
23	Ctrl	1.030±0.234	0.087±0.021	0.373±0.081	0.633±0.108	0.672±0.218	0.063±0.027	0.584±0.255	0.642±0.118	0.508±0.079	1.043±0.721
		Dry Season									
S/N	Sample Code	Pb (mg/kg)	Hg (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	B (mg/kg)
24	DR1	0.560±0.621	0.000±0.000	0.932±0.031	0.067±0.218	0.482±0.108	5.414±0.084	0.036±0.068	1.030±0.021	0.556±0.083	0.253±0.069
25	DR2	0.670±0.219	0.000±0.089	0.527±0.068	0.167±0.318	0.563±0.109	2.292±0.021	0.043±0.010	2.970±0.062	0.768±0.083	1.106±0.521
	$\overline{X}$	0.615±0.42	0.000±0.045	0.730±0.050	0.117±0.268	0.523±0.109	3.853±0.525	0.040±0.039	2.000±0.042	0.662±0.083	0.680±0.295
26	Ctrl	0.976±0.234	0.003±0.021	1.203±0.081	0.367±0.108	0.572±0.218	2.169±0.027	0.000±0.255	1.758±0.118	0.408±0.079	1.003±0.721
(WHO (mg/kg)		0.3-10	0.001-0.04	10	0.002-0.2	100-1000	12-60	1-12	0.1	0.1-5	NA
NESREA (mg/kg)		0.1	0.0005	0.05	NA	0.5	NA	0.01	NA	NA	NA

Values are mean± standard deviations (n=3).

Key: DR= Doma Road; Ctrl= Control; NA= Not Available

Table 6: Concentrations of Heavy Metals in Samples from Refuse Dumpsites in Gandu (Telecom Mast/Students' Village)

		Wet Season									
S/N	Sample Code	Pb (mg/kg)	Hg (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	B (mg/kg)
27	TM1	0.547±0.048	0.000±0.000	0.126±0.058	1.560±0.083	0.540±0.075	0.091±0.031	0.274±0.078	0.973±0.094	0.707±0.072	1.015±0.051
28	TM2	0.177±0.116	0.000±0.000	0.414±0.082	0.920±0.073	0.670±0.085	0.086±0.011	0.382±0.085	0.752±0.073	0.468±0.110	0.529±0.084
	$\bar{X}$	0.362±0.082	0.000±0.000	0.270±0.70	1.240±0.078	0.605±0.080	0.089±0.021	0.328±0.082	0.863±0.084	0.588±0.091	0.772±0.068
29	Ctrl	0.533±0.017	0.000±0.000	0.036±0.011	1.075±0.062	0.273±0.051	0.043±0.007	0.511±0.041	0.537±0.082	0.949±0.084	0.792±0.083
		Dry Season									
S/N	Sample Code	Pb (mg/kg)	Hg (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	B (mg/kg)
30	TM1	0.357±0.048	0.000±0.000	0.120±0.058	1.340±0.083	0.440±0.075	0.070±0.031	0.176±0.078	0.847±0.094	0.607±0.072	1.005±0.051
31	TM2	0.167±0.116	0.000±0.000	0.314±0.082	0.820±0.073	0.862±0.085	0.097±0.011	0.274±0.085	0.702±0.073	0.438±0.110	0.436±0.084
	$\bar{X}$	0.262±0.082	0.000±0.000	0.217±0.070	1.080±0.078	0.651±0.080	0.084±0.021	0.225±0.082	0.775±0.084	0.523±0.091	0.721±0.068
32	Ctrl	0.503±0.017	0.000±0.000	0.032±0.011	0.763±0.062	0.237±0.051	0.032±0.007	0.321±0.041	0.438±0.082	0.845±0.084	0.672±0.083
(WHO (mg/kg)		0.3-10	0.001-0.04	10	0.002-0.2	100-1000	12-60	1-12	0.1	0.1-5	NA
NESREA (mg/kg)		0.1	0.0005	0.05	NA	0.5	NA	0.01	NA	NA	NA

Values are mean± standard deviations (n=3).

Key: TM= Telecom Mast; Ctrl = Control; NA= Not Available

Table 7: Concentrations of Heavy Metals in Soil Samples from Refuse Dumpsites in Tudun Abu (Shendam Road)

S/N	Sample Code	Pb (mg/kg)	Hg (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	B (mg/kg)
	Wet Season										
33	TASR1	0.252±0.078	0.228±0.073	0.000±0.000	0.117±0.064	0.288±0.085	0.169±0.094	0.184±0.082	0.961±0.092	0.411±0.072	1.496±0.627
34	TASR2	0.140±0.085	0.367±0.086	0.249±0.094	0.277±0.042	0.166±0.072	0.102±0.042	0.303±0.087	1.385±0.032	0.845±0.055	0.184±0.052
	$\overline{X}$	0.196±0.082	0.298±0.080	0.125±0.047	0.197±0.053	0.227±0.079	0.136±0.068	0.244±0.085	1.173±0.062	0.628±0.064	0.840±0.340
35	Ctrl	1.090±0.740	0.027±0.084	0.137±0.048	0.788±0.070	0.597±0.036	0.143±0.082	0.866±0.007	0.908±0.093	0.653±0.091	0.997±0.062
	Dry Season										
S/N	Sample Code	Pb (mg/kg)	Hg (mg/kg)	As (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	B (mg/kg)
36	TASR1	0.425±0.078	0.123±0.073	0.000±0.000	0.108±0.064	0.276±0.085	0.223±0.094	0.253±0.082	0.843±0.092	0.318±0.072	1.362±0.627
37	TASR2	0.216±0.085	0.345±0.086	0.020±0.094	0.326±0.042	0.176±0.072	0.216±0.042	0.268±0.087	0.946±0.032	0.346±0.055	0.174±0.052
	$\overline{X}$	0.321±0.082	0.234±0.080	0.010±0.047	0.217±0.053	0.226±0.079	0.220±0.068	0.261±0.085	0.895±0.062	0.332±0.064	0.768±0.340
38	Ctrl	0.986±0.740	0.018±0.084	0.114±0.048	0.792±0.070	0.586±0.036	0.123±0.082	0.768±0.007	0.926±0.093	0.562±0.091	0.086±0.062
(WHO (mg/kg)		0.3-10	0.001-0.04	10	0.002-0.2	100-1000	12-60	1-12	0.1	0.1-5	NA
NESREA (mg/kg)		0.1	0.0005	0.05	NA	0.5	NA	0.01	NA	NA	NA

Values are mean± standard deviations (n=3).

Key: TASR= Tudun Abu (Shendam Road); Ctrl= Control; NA=Not Available

Pb

In this study, the mean metal concentration of Pb ranged between 0.196±0.082 mg/kg in Tudun Abu in wet season (Table 7) to 0.670±0.042 mg/kg at Tudun Amba (Table 5) in dry season.
The concentrations are below the threshold limits by WHO, 2014 (10 mg/kg) [30], and above that of NESREA, 2011 (0.1 mg/kg) [31]. The mean metal concentration is higher in dry season compared to wet season.

Lead is a toxic heavy metal which can be taken up by plant from the soil thereby interfering with the food chain, and is reported to exert its most significant effect on the nervous system. [32-33] also confirmed that the high concentrations of Pb in soil samples in refuse dumpsites could be as a result of disposal of wastes, livestock manures, atmospheric deposition from anthropogenic sources such as motor vehicle emissions, or automobile mechanical workshop areas.

Hg

The concentration of Hg is beyond detectable limit at Tudun Amba (Table 5) in dry season, and also at Gandu (Table 6) in wet and dry seasons. However, in wet season, the mean Hg concentration was highest (0.332 mg/kg) at Millionaire's Quarters (Table.4), compared to the highest value (0.234 mg/kg) at Tudun Abu (Table 4) during the dry season. The results obtained are above the permissible limits set by WHO (0.04 mg/kg), NESREA (0.0005 mg/kg).

The concentrations observed for Hg are above the WHO, and NESREA values of 0.04 and 0.0005 mg/kg respectively [34-36]. This observation could be attributed to improper disposal of electrical equipment like thermometers, fluorescent bulbs or electronic devices that contain mercury that were seen in the dumpsites which may have been released into the soil. The elevated concentration of mercury could also be attributed to incineration of wastes that contain mercury, such as medical wastes or batteries that release mercury into the air which eventually settles in the soil. Heavy metals are major components of these wastes and have been implicated in several metal-related diseases and food poisoning in man as corroborated in previous studies [33, 37-39].

As

The mean metal concentration of As range from 0.010 mg/kg at Tudun Abu (Table 7) in dry season to 0.865 mg/kg at Kwandare (Table 3) in dry season. The result is below the threshold limit set by WHO (10 mg/kg), and above that of NESREA (0.05 mg/kg).

Arsenic has been implicated in lung cancer, especially when arsenic compound inhaled is of low solubility. It has also been reported to have an effect on the liver by causing the disease termed cirrhosis [25].

Cr

The mean metal concentration of Cr range between 0.117 mg/kg at Tudun Amba (Table 5) in dry season to 1.667 mg/kg at Kwandare (Table 3) in dry season. The concentrations of Cr are above the maximum threshold limit of 0.2 mg/kg (WHO). The high concentrations of Cr could be attributed to disposal of items like leather or textiles that may have been treated with chromium compounds. The concentration ranges of Cr recorded agrees with the range of values in soil samples [40].

Even in small amount, Cr is essential to human nutrition in the utilization of glucose, stimulates the growth of agricultural crops, while excess of it, however, promotes various diseases [41].

Fe

The highest mean value of 0.667 mg/kg was recorded at Millionaires Quarters (Table 4) in dry season. The values are below the reference standard of WHO (1000 mg/kg).

The concentration of Fe, could be partly due to presence of Fe-based waste materials deposited through domestic and industrial wastes [42 - 43]. In human metabolism, Fe is essential in the transport and storage of oxygen [44].

The major sources of Fe in these soils could be due to metallic scraps being co-deposited with domestic wastes, and industrial wastes.

Zn

The mean metal concentration ranges between 0.084 mg/kg in Gandu (Table .6) in dry season, to 3.853 mg/kg in Tudun Amba (Table .5) in dry season. The values are below the maximum permissible limit by WHO (60 mg/kg). In human nutrition, Zn is an essential element, and plays important role in the elimination of carbon dioxide, protein digestion, and is a cofactor in numerous enzymes, necessary for growth, healing and overall health. The presence of Zn in soils [43], could be attributed to the occurrence of dry cells in the municipal waste and burning of electronic gadgets [40].

Cu

The mean metal concentration of Cu range from 0.040 mg/kg at Tudun Amba (Table .5) in dry season, to 0.930 mg/kg in Kwandare (Table 3) in dry season. The concentrations of Cu are below the maximum threshold limits of WHO (12 mg/kg). Cu is an essential trace element in human nutrition, in the synthesis of haemoglobin, cell energetics, and a cofactor in redox enzymes. However, Cu can be toxic, at high concentration [45], while at low concentrations, it can cause headache, nausea, vomiting and diarrhea. The concentration of Cu in the various soils investigated are below the reference values. This suggest little or no contribution of the burning of electronic gadgets and other Cu-based wastes such as automobile spare parts to the presence of Cu [33].

Mn

In the soil samples investigated, the mean metal concentration of Mn range between 0.390 mg/kg in Kwandare (Table 3) in dry season, to 2.318 mg/kg in Millionaires' Quarters (Table 4).

The values recorded are above the maximum permissible limit of 0.1 mg/kg. Manganese is essential in human metabolism, in cell energetics, cofactor in numerous enzymes, necessary for carbohydrate metabolism and bone formation [43]. The concentrations of Mn in these locations may also be attributed to the improper disposal of batteries, electronic devices or household products that contain Manganese which may accumulate in the soil as reported [46].

Ni

The mean metal concentration of Ni range between 0.184 mg/kg at Kwandare (Table 3) in dry season, and 0.747 mg/kg at Tudun Amba (Table 5) in wet season. The values are below the threshold limit of 5 mg/kg by WHO. Nickel aids in the use of Fe and Cu in living organism. The presence of Ni could be due to anthropogenic origin such as leaching from metal scraps, runoff of paints/pigment waste, discharge from sewage and indiscriminate waste dumps [43].

B

The mean metal concentration of B in the investigated soils ranges between 0.409 mg/kg at Millionaires' Quarters (Table 4) in dry season, to 0.840 mg/kg at Tudun Abu (Table 7) in wet season. The permissible limits are not available for B to be compared, partly due to the fact that soil pollution problems of B are less significant than those associated with some other heavy metals.

Commonly regulated metals are Pb, Hg, As, Cd, Cr, Ni. These metals confer greater health and environmental hazard with a high probability of food chain contamination. The results obtained for Hg, Cr, and Mn are consistent with the findings of the municipal wastes in most urban areas [47].

However, the concentrations of Pb, As, Fe, Zn, Cu and Ni in the remaining locations of the different soils are below the maximum tolerable limit and pose no risk to the environment at the moment. The low levels of heavy metals in this study agree with the findings [10,28,48], and might be due to low level of deposition of heavy metal-containing waste at the dumpsites.

The decreasing order of heavy metal concentrations in soils investigated across the locations, and seasons is: Mn > Cr > Hg > Ni > Pb > Cu > Fe > Zn > As > B.

The concentrations of Hg, Cr, and Mn across the locations were above the WHO threshold limits in both wet and dry seasons. However, most of the locations during the dry season recorded significantly higher concentrations of Hg, Cr, and Mn than the wet season, particularly in Northern, Central, and Western part of Lafia metropolis, while the Southern and Eastern part recorded less within the same period. This could be due to different characteristics possessed by different soil types or composition [5]. Thus, the total concentrations of metals obtained during the dry season were higher than those in wet season. This might be due to the effect of rainfall which may facilitate the leaching of soil which contributes to dilution of soil [49]. However, during the dry season, open dumping, burning of wastes as was observed in some of the locations, evaporation of water from soil becomes intense, thereby increasing the metal concentration in soil [50]. In the same pattern, the concentrations of Pb, As, Fe, Cu, Zn, and Ni fall below the threshold limit, as in the case during the wet season.

CONCLUSION AND RECOMMENDATIONS

The research assessed, the concentrations of heavy metals from selected soil samples in refuse-dumpsites in Lafia Metropolis. Results of heavy metals in soil samples from the selected waste dumpsites indicated high concentrations of Hg, Cr and Mn above the threshold limit of WHO, and NESREA in all the locations or dumpsites.

Based on the findings, the study recommends as follows:

1) The relevant government bodies should be encouraged to reduce the number of waste dumpsites in Lafia Metropolis.
2) Residents, policy makers and governments in the study area should embrace adequate sanitation strategies, arising from potential environmental risks associated with the use refuse dumpsite soil for arable farming and consumption of plants growing around the dumpsites with respect to heavy metal toxicity.
3) It is recommended that the data obtained from the study be used by the relevant authorities, residents and farmers to broaden their knowledge on the risk accompanying waste dumpsites.
4) Due to toxicity of heavy metals, the use of manure from the dumpsites for agricultural purposes should be discouraged as plants and vegetables can easily absorb them.
5) Phytoremediation of these heavy metals is necessary for the clean-up of the environment from these toxic metals by relevant government agencies.

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