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ASSESSMENT OF HEAVY METAL CONCENTRATIONS AND PHYSICOCHEMICAL PARAMETERS IN SOILS OF SELECTED REFUSE DUMPSITES IN FIVE GEOGRAPHICAL ZONES OF LAFIA METROPOLIS, NIGERIA

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ABSTRACT

The disposal of solid wastes has become a very serious problem particularly in most Nigerian cities due to rapid population explosion and commercial activities. Lafia metropolis, the capital city of Nasarawa State, Nigeria is experiencing rapid urbanization as a result of population growth, and unplanned development accompanied by indiscriminate waste disposal. In this study, concentrations of heavy metals and physicochemical parameters from 20 soil samples each from selected refuse dumpsites in wet and dry seasons were determined using Atomic Absorption Spectrophotometer and Association of Official Analytical Chemists (AOAC) standard methods. The results showed that during the wet season the concentration of heavy metals; Hg (0.100 mg/kg – 0.367 mg/kg), Cr (0.117 mg/kg – 0.926 mg/kg), and Mn (0.480 mg/kg – 1.385 mg/kg) were above the maximum permissible limits (0.04 mg/kg), (0.2 mg/kg), (0.1 mg/kg) of World Health Organisation (WHO), and (0.0005 mg/kg for Hg) of National Environmental Standards 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 concentrations of Hg (0.123 mg/kg - 0.345 mg/kg), Cr (0.067 mg/kg – 2.833 mg/kg), and Mn (0.702 mg/kg – 3.091 mg/kg) across the locations were also found to be above the tolerable limits. Except for nitrates in wet season (131.36 mg/L – 1,312.15 mg/L), phosphates (0.12 mg/L – 7.86 mg/L) and organic matter (2.19% w/w – 3.24 % w/w), dry season for nitrates (176.84 mg/L – 1,755.21 mg/L), phosphates (0.26 mg/L – 14.39 mg/L), organic matter (2.82% w/w – 3.23 % w/w) which were above WHO standards of 30 mg/L, 4.5 mg/L and 3% w/w respectively, other results obtained for physicochemical parameters during the wet season were low and within permissible limit. The results obtained during the dry season were generally higher when compared to that of the rainy season except for moisture content. Therefore, appropriate government agencies should integrate the regular monitoring of waste disposal into its developmental plan and framework in order to prevent excessive build-up of these metals in humans through the food chain, to avoid jeopardizing our health and preventing harm to the environment.

Keywords: Heavy metal pollution, Physicochemical parameters, Refuse dumpsites, Solid waste

INTRODUCTION

The regular assessment of heavy metals within the environment, drinking water, waste dumpsites, food and biological fluids has become essential due to the increased environmental impacts and stringent regulations for pollution control. The inefficient management and uncontrollable disposal of the municipal solid waste (MSW) in big cities, especially in developing countries like Nigeria, causes serious problem to the environment. Dumping of solid wastes create environmental pollution related to toxins, leachate and greenhouse gases which are growing environmental concern (Spela *et al.*, 2013; Lekan *et al.*, 2020; Ngoc *et al.*, 2021).

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 (Akaeze, 2001; Saanu and Josephine, 2017). Going by the resource and energy demand on the environment and the internal pollution that man inflicts upon himself by inhalation and ingestion of alien chemical substances, man is best described as a chemical factory in terms of material use and waste (Gary and Stephen, 2000).

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 infiltration of chemical substances above their threshold limit into the environment. Reports have shown that solid waste introduces additional heavy metals into the surrounding soil and ground water. 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 (Obasi *et al.*, 2012). The municipal solid wastes (MSW) are undesirable materials mainly consisting of heavy metals. 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 (Ekeu-wei *et al.*, 2018; Saida *et al.*, 2019).

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 indeed 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 the population of Lafia by 2006 National Population Census is 330,712. The study further projected the population to 563,004 by 2024, at a growth rate of 3% (Banki et al., 2019; NPC, 2023). This remarkable 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 (Adewuyi and Opasina,

2010). Similar observations have been noted in Nigerian and African cities where thousands of tons of solid waste are generated daily, with indiscriminate dumping of these solid wastes in open places (Besufekad *et al.,* 2020). Poor waste management, improper collection and disposal of refuse are among the key factors responsible for the multiple problems threatening not only Lafia but also in many parts of the country. Many heavy metals; Pb, Hg, As, Cd, Ba, Ag which are known poisons are also present in wastes (Iwegbue *et al.,* 2007).

Most of the heavy metals enter the food chain via plant uptake. Vegetables absorb these metals from the ground, as well as from deposits on the parts of vegetables exposed to air from polluted environment. Recent studies have also reviewed that waste dumpsites can transfer significant levels of these toxic and persistent metals into the soil environment (Ebong *et al.,* 2008).

The aim of the research is to assess the concentration of heavy metals and physicochemical parameters from soil samples in selected refuse-dumpsites in Lafia metropolis. The environmental impacts of these heavy metals worsen public health risks as contaminants infiltrate food, water, and air, leading to various problems. Therefore, adequate information on the composition of the municipal solid waste and its environmental impacts are essential for addressing these challenges.

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, potassium chloride, all of Analytical Grade. Distilled water was used for the preparation of solution.

Apparatus

The apparatus used were beakers, flasks, pipettes, burettes, digestion apparatus, filtration apparatus, glass bottles, polythene bags, plastic containers, sample labels and markers, gloves and protective clothing, sampling tools (soil Auger, trowel, core sampler), thermometer, pH meter, conductivity meter, Global Positioning System (GPS) device.

Equipment and Instruments

The equipment and instruments used in the study were: Analytical balance, centrifuge, reflux condenser, spectrophotometer, Atomic Absorption Spectrophotometer, oven or muffle furnace, fume cupboard.

Description of the Study Area

The study area is Lafia Metropolis 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 7º and 9º 37'E of the Greenwich meridian and has an altitude of 600 m above sea level (Ayi, 2003; Akwa *et al.,* 2007). 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 fourth largest Local Governments in that order.

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 (Ebuga *et al.,* 2021).

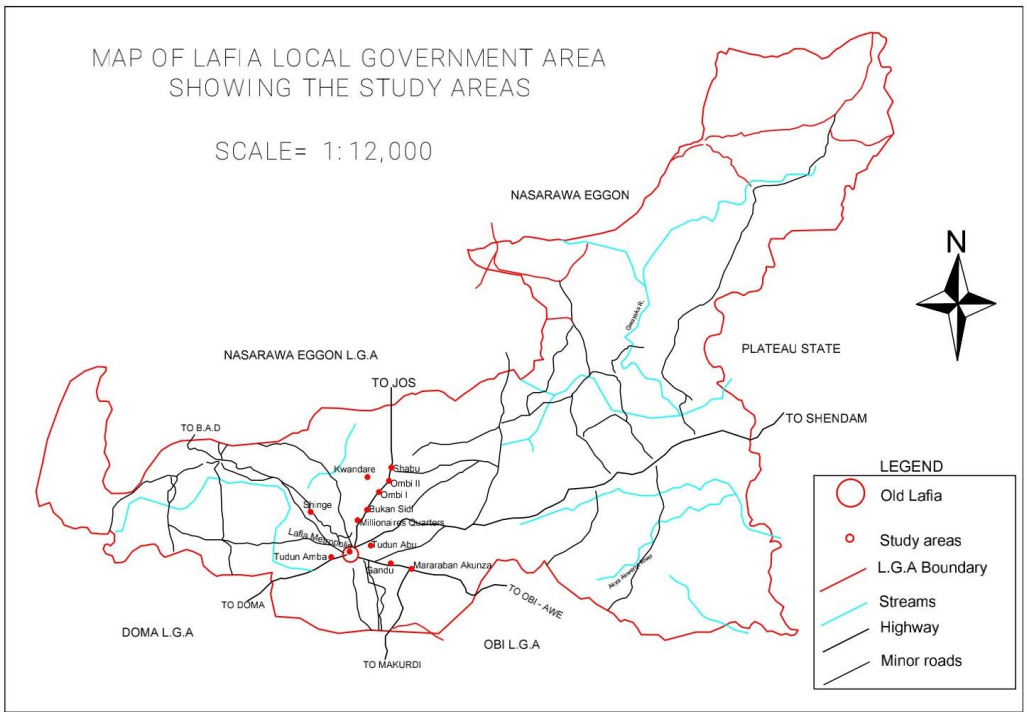

Figure 1: Map of Lafia Local Government Area showing the study sites

Methods

Sample collection

Soil samples (wastes) were collected at 0-15 cm below the topsoil with the aid of soil Auger, from thirty-eight (28) refuse dumpsites and twelve (10) 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 sampling units cut across twelve major locations or positions namely; Ombi II, Bukan Sidi, Tudun Amba, Gandu and Tudun Abu. Each sampling unit from the refuse dumpsites was 50 m, 100 m apart and the control was far away from refuse dumpsites. Composite of individual units of three samples were taken from each dumpsites (Rasool *et al.*, 2007; Anake *et al.*, 2009; Aremu *et al.*, 2010; Opaluwa *et al.*, 2012).

Table 1: Geographical locations of sampling sites

S/N	Location	Sites	No. of samples collected	
			Wet	Dry
1	Northern part of Lafia Local Government Area	Ombi II	2	2
2	Central part of Lafia Local Government Area	Bukan Sidi	2	2
3	Western part of Lafia Local Government Area	Tudun Amba	2	2
4	Southern part of Lafia Local Government Area	Gandu	2	2
5	Eastern part of Lafia Local Government Area	Tudun Abu	2	2
		Total	**10**	**10**

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 taken to the Muhammadu Buhari TETfund Centre of Excellence (MBTCE), FULAFIA 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, far away from each of the dumpsites were determined. Results obtained were expressed as mean ± standard deviation of three replicate measurements.

Global Positioning System: Coordinates and Elevation of the Sampling Sites

With the use of Global Positioning System meter (GPS ETREX Garmin), the coordinates and elevations of each sampling points were measured and the results were recorded (Vincent *et al.*, 2012; Nabil *et al.*, 2014; Ediene and Umoefok, 2017).

Table 2: Geographical positions of soil samples taken from refuse dumpsites in different geographical zones

S/No	Location	Northing	Easting	Altitude (m)
1	Ombi II (Poly Guest House)	440404	946525	162
2	Ombi II (Deeper Life)	449519	946551	166
3	Bukan Sidi (Omgbolo Street)	447525	942751	159
4	Bukan Sidi (MOWA)	446927	942140	182
5	Tudun Amba (DOMA Road)	446778	938965	182
6	Tudun Amba (DOMA Road)	446772	938964	187
7	Gandu (Telecomm Mast)	452532	937578	178
8	Gandu (Telecomm Mast)	452525	937577	178
9	Tudun Abu (Shendam Road)	451480	941038	202
10	Tudun Abu (Shendam Road)	451474	941045	201

Physicochemical Analysis of Samples

The physicochemical analysis of the soil samples was determined according to the Association of Official Analytical Chemists (2013) standard methods. The pH, temperature was determined *in situ* and recorded at the sampling sites. Nitrates, Phosphates, Chlorides, Sulphates and other physical parameters such as BOD, COD, TDS, DO, were determined using standard methods (Vincent *et al.*, 2012; Henry *et al.*, 2017; Thelma *et al.*, 2020).

Determination of pH and Temperature

The pH of the soil samples was determined by adding 10 g of air dried and sieved soil sample to 25 mL of distilled water. The mixture was stirred and allowed to stand for 30 minutes. The electrode of the calibrated pH meter was immersed into the slurry (partially settled suspension) and readings were taken. The temperature of the soil was obtained by pushing the soil thermometer into the soil until the tip is 7 cm below the soil surface. The soil temperature was read after 2 min (Obaliagbon *et al.*, 2006; Adewuyi and Opasina, 2010; Saida *et al.*, 2019).

Moisture Content

Moisture content was determined by laboratory measurements using standard procedures as adopted and reported by Akinbile *et al.*, (2016).

A portion (1 g) of a representative sample of the soil was placed in a clean core sampler of known mass, the mass of the container and soil sample to be determined (W_2) using an analytical balance. The core sampler was placed in an oven maintained at 110±5ºC for 4 h to obtain a constant weight (W_1). The measurement was done and the percentage moisture was calculated as follows:

$$\text{Moisture} = \frac{(W_2 - W_1)}{W_1} \times 100$$

Where;

W_2 = weight of core sampler + weight of sample before oven drying:

W_1 = weight of core sampler + weight of sample after oven drying (Olayinka *et al.,* 2007). The moisture content of the soil is an indication of the amount of water present in the soil.

Organic Carbon and Organic Matter Determination

Organic carbon and organic matter determination was carried out by chromic acid oxidation or dichromate wet oxidation method of Walkley and Black (Arshi and Khan, 2018). The soil sample was oxidized by potassium dichromate solution in the concentrated acid medium. The excess potassium dichromate was titrated with ferrous ammonium sulphate, which is a reducing agent. The percentage organic matter (M_O) was deduced from the percentage of organic carbon using a specific M_O to C factor. The percentage of organic carbon was calculated as follows;

% Organic C = $\frac{N\ (T-B)}{W}$ x 0.390

Where N= Normality of $KMnO_4$;

T = Volume of $KMn0_4$ used in titration of soil or sample titre value

B = Volume of $KMnO_4$ used in titration of blank (Blank titre value)

W = Weight of air-dried soil sample in grams.

% Organic Matter = % Organic Carbon x 1.724 (Badmus *et al.,* 2014; Musa *et al.,* 2020; *Ruth et al.,* 2021).

Electrical Conductivity (EC)

Electrical conductivity (EC) was determined from the filtrates obtained from the suspension for pH analysis using conductivity meter. The electrical conductivity (EC), expressed in micro-Siemens cm^{-1} of the soil was monitored as reported by Saida *et al.,* (2019).

Other Parameters

TDS, DO, COD, BOD, NO_3^-, PO_4^{2-}, Cl^-, SO_4^{2-}, were determined as outlined by Adewuiyi and Opasina, (2010); Obasi *et al.,* (2012); NO_3^-, by Phenoldisulphonic acid method. PO_4^{2-} was analyzed colorimetrically by molybdophosphoric acid, while Cl^- was determined by Volhard method. Sulphate was determined by gravimetric method. TDS, DO, COD, BOD were determined according to standard methods by AOAC (2013).

Digestion of Samples and Determination of Heavy metals

Two gram (2.0 g) of the sieved soil samples were digested for 3 hours at 85ºC 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 allowed to cool to room temperature and then diluted with distilled water and adjusted to zero mark. The mixture was then transferred into a 100 mL volumetric flask after filtering using Whatman No. 42 filter paper and adjusted to zero mark with distilled water. The extracts (digested soil waste samples) were analyzed for the heavy metals; Pb, Hg, Cd, Cr, Fe, Zn, Cu, Mn, Ni, using AAS (Oketola and Akpotu, 2013; Saida *et al.,* 2019).

RESULTS AND DISCUSSION

The results of the heavy metals of soil samples and physicochemical parameters of soil samples from refuse dumpsites were obtained in September 2021 for the wet season and March 2022 for the dry season in Lafia Metropolis are presented in Tables 3 – 4. The results obtained are discussed in each of the tables presented.

Table 3 showed the results of concentration of heavy metals across different geographical location in wet and dry seasons. The results showed elevated concentration of Hg, Cr, and Mn above the maximum objectionable limit of World Health Organisation (WHO) and National Environmental Standards and Regulations Enforcement Agency (NESREA). In wet season, the concentrations of Hg across the sampling units ranged from 0.100 mg/kg in the second sampling point of refuse dumpsite in Doma Road to 0.367 mg/kg of the second sampling point of Tudun Abu. In dry season, the concentrations of Hg across the sampling units ranged from 0.123 mg/kg in the first sampling point of Tudun Abu to 0.345 mg/kg of the second sampling point of Tudun Abu. The concentrations observed for Hg were above the WHO threshold limit of 0.04 mg/kg and 0.0005 mg/kg set by NESREA (Edieme and Umoetok, 2017; Adeyemi-Ale *et al.,* 2018; Agbeshie *et al*., 2020; Franklin *et al*., 2020). The results obtained could be attributed to disposals or emissions of metal wastes from municipal areas into the soil environment. Heavy metals are major components of these wastes and have been implicated in several metal-related diseases and food poisoning in man (Raymond and Felix, 2011; Chessed *et al.,* 2018).

The concentrations of Chromium (Cr) in wet season range from 0.117 mg/kg in the first sampling point of Tudun Abu to 0.926 mg/kg of the first sampling point of Deeper Life above the maximum threshold limit of 0.2 mg/kg (WHO). While in dry season, the concentrations of Chromium (Cr) range from 0.067 mg/kg of the first sampling point of Doma Road to 2.833 mg/kg of the first sampling point of Poly Guest House above the maximum threshold limit of 0.2 mg/kg (WHO). The high concentrations of Chromium could be attributed to disposal of electronic wastes, used refrigerators, used computers, cables (Vodyanitskii, 2016; Benedicta *et al.,* 2017).

In wet season, concentrations of Manganese (Mn) range from 0.480 mg/kg of the first sampling point in Doma Road to 1.385 mg/kg of the second sampling point of Tudun Abu above the threshold limit of 0.1 mg/kg. In dry season, the concentrations of Manganese (Mn) range from 0.702 mg/kg of the second sampling point in Gandu to 3.091 mg/kg of the first sampling point of Deeper Life above the threshold limit of 0.1 mg/kg. The concentrations of Mn in these locations are attributed to the disposal of household products and electronic devices that contain this metal (Iwegbue *et al.,* 2010; Nnorom and Osibanjo, 2021).

Considering the two seasons, the concentrations of Hg, Cr, Mn obtained during the dry season are higher than that of wet season. This might be due to the effect of rainfall in wet season which facilitates dilution of the soil through leaching (Durosimi *et al*, 2018).

However, the concentrations of Lead (Pb), Arsenic (As), Iron (Fe), Zinc (Zn), Copper (Cu) and Nickel (Ni) in the remaining locations of the different dumpsites in Shabu were below the maximum tolerable limit and pose no risk to the environment. Soil is a major sink of heavy metals released into the environment by industrial and human activities and most heavy metals commonly found at contaminated refuse dumpsites are Pb, Hg, As, Cd, Cr, Cu, Zn, and Ni (Edieme and Umoetok, 2017; Lekan *et al.,* 2020).

Table 3: Concentrations of Heavy Metals of soil samples from Refuse Dumpsites at different Geographical Locations

S/N	Wet Season										
	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	PGH1	0.005±0.001	*0.352*±0.041	1.082±0.357	0.482±0.055	0.322±0.086	0.153±0.037	0.296±0.061	0.827±0.087	0.370±0.038	0.590±0.095
2	DL1	0.527±0.103	0.359±0.107	0.358±0.103	0.926±0.104	0.244±0.021	0.518±0.115	0.578±0.082	0.863±0.083	0.571±0.051	0.373±0.030
3	OH1	0.910±0.201	*0.238*±0.027	0.312±0.047	0.587±0.108	0.320±0.085	0.139±0.085	0.204±0.063	0.525±0.026	0.545±0.041	0.439±0.108
4	MO1	0.648±0.255	0.331±0.027	1.447±0.487	0.415±0.209	0.324±0.038	0.239±0.085	0.231±0.107	0.700±0.017	0.525±0.048	0.926±0.096
5	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
6	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
7	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
8	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
9	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
10	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
S/N	**Dry Season**										
	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	PGH1	0.360±0.001	*0.000*±0.041	0.122±0.357	2.833±0.055	0.222±0.086	4.686±0.037	1.275±0.061	2.424±0.087	0.670±0.038	0.690±0.095
2	DL1	0.060±0.103	0.217±0.107	1.608±0.103	0.667±0.104	0.344±0.021	6.370±0.115	1.273±0.082	3.091±0.083	0.672±0.051	0.573±0.030
3	OH1	0.160±0.201	*0.150*±0.027	0.000±0.047	2.167±0.108	0.337±.085	0.537±0.085	0.333±0.063	1.394±0.026	0.565±0.041	0.739±0.108
4	MO1	0.160±0.255	0.150±0.027	1.563±0.487	4.500±0.209	0.605±0.038	4.620±0.085	0.023±0.107	2.364±0.017	0.603±0.048	0.866±0.096
5	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
6	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
7	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
8	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
9	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
10	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
(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

Key: PGH – Poly Guest House; MO – MOWA; DL – Deeper Life; DR – Doma Road
OH – Omgbolo Hotel; TM – Telecom Mast (Gandu); NA – Not Available; TA – Tudun Abu (Shendam Road)

Table 4: Physicochemical Results of Soil Samples from Refuse Dumpsites at different Geographical Locations

Sample Code	pH	Temp. (° C)	EC *(µS/cm)*	Moisture Content (%)	Organic Carbon %(w/w)	Organic Matter %(w/w)	TDS mg/L	COD mg/L	BOD mg/L	DO mg/L	NO_3^- mg/L	PO_4^{2-} mg/L	Cl^- mg/L	SO_4^{2-}mg/L
	Wet Season													
1 PGH1	7.3±0.7	28.2±0.9	*88.6*±0.0	7.18±0.1	1.89±0.5	3.24±0.6	40.0±0.0	2.20±0.5	4.20±0.1	6.00±0.5	973.21±0.0	7.11±0.1	31.91±0.6	25.37±0.0
2 DL1	7.1±0.0	28.7±0.8	72.0±0.4	6.39±0.0	1.70±0.8	2.93±0.5	30.0±0.9	2.30±0.2	3.20±0.2	5.50±0.4	1210.11±0.0	0.12±0.1	35.14±0.0	23.46±0.1
3 OH1	7.7±0.3	29.4±0.0	79.0±0.5	9.14±0.9	1.28±0.7	2.19±0.2	30.0±0.7	1.20±0.5	2.40±0.2	4.7±0.0	967.13±0.1	0.53±0.7	24.21±0.2	11.36±0.0
4 MO1	7.9±0.5	29.0±0.7	64.3±0.7	10.70±0.2	1.83±0.6	3.15±0.6	50.0±0.7	2.20±0.4	2.40±0.4	5.6±0.1	1312.15±0.4	7.21±0.5	3.05±0.8	3.86±0.5
5 DR1	7.08±0.3	28.5±0.4	55.5±0.6	11.85±0.3	1.82±0.8	3.13±0.5	40.0±0.6	2.01±0.7	2.00±0.6	5.1±0.2	736.21±0.9	7.86±0.6	14.18±0.3	14.06±0.1
6 DR2	6.39±0.6	28.6±0.3	28.8±0.1	6.37±0.4	1.80±0.2	3.12±0.2	20.0±0.2	1.20±0.3	3.2±0.3	5.5±0.5	731.01±0.6	7.80±0.6	35.45±0.5	11.20±0.4
7 TM1	6.71±0.9	29.5±0.4	17.5±0.5	4.49±0.6	1.64±0.2	2.82±0.5	10.0±0.4	10.18±0.4	2.20±0.8	5.80±0.1	131.36±0.2	0.67±0.3	14.18±0.4	6.30±0.2
8 TM2	6.54±0.5	28.4±0.5	75.4±0.4	3.84±0.5	1.78±0.3	3.02±0.3	10.0±0.6	9.11±0.2	4.20±0.9	6.70±0.8	742.00±0.2	1.03±0.9	24.35±0.0	8.67±0.5
9 TASR1	6.86±0.5	28.6±0.6	46.00±0.8	3.21±0.1	1.82±0.5	3.14±0.4	24.42±0.4	2.01±0.2	3.20±0.7	5.60±0.4	936.70±0.6	0.31±0.3	30.28±0.5	11.21±0.1
10TASR2	7.90±0.0	29.5±0.1	30.40±0.2	3.50±0.3	1.80±0.2	3.10±0.2	14.48±0.2	2.30±0.6	2.40±0.8	5.70±0.7	946.31±0.5	2.96±0.8	7.09±0.8	10.26±0.4
	Dry Season													
Sample Code	**pH**	**Temp. (° C)**	**EC *(µS/cm)***	**Moisture Content (%)**	**Organic Carbon %(w/w)**	**Organic Matter %(w/w)**	**TDS mg/L**	**COD mg/L**	**BOD mg/L**	**DO mg/L**	**NO_3^- mg/L**	**PO_4^{2-} mg/L**	**Cl^- mg/L**	**SO_4^{2-}mg/L**
1 PGH1	7.43±0.6	30.6±0.2	*153.3*±0.0	0.92±0.2	1.88±0.7	3.23±0.4	120±0.2	2.10±0.2	0.00±0.0	4.20±0.4	1755.21±0.0	12.21±0.2	74.45±0.2	33.74±0.1
2 DL1	7.41±0.2	32.4±0.3	175.4±0.4	0.23±0.3	1.82±0.3	3.13±0.4	170±0.2	2.10±0.4	0.00±0.0	2.20±0.2	1608.42±0.2	0.26±0.3	85.08±0.3	36.73±0.1
3 OH1	7.16±0.2	34.5±0.2	*116.3*±0.1	0.50±0.4	1.88±0.1	3.23±0.2	70±0.0	2.10±0.1	4.00±0.1	6.20±0.2	1376.84±0.1	0.63±0.6	21.27±0.1	17.26±0.1
4 MO1	7.94±0.3	35.6±0.3	98.9±0.6	0.40±0.1	1.78±0.3	3.05±0.1	50±0.6	0.10±0.0	0.00±0.6	4.20±0.0	1524.21±0.4	14.24±0.4	66.87±0.6	23.21±0.0
5 DR1	8.88±0.4	38.9±0.6	*39.8*±0.1	0.61±0.1	1.78±0.4	3.05±0.1	20±0.4	1.10±0.1	2.00±0.4	4.20±0.3	176.84±0.6	14.39±0.1	42.56±0.3	24.82±0.2
6 DR2	8.32±0.2	39.7±0.4	60±0.2	0.84±0.2	1.82±0.1	3.13±0.3	30±0.2	2.10±0.3	4.00±0.5	6.20±0.2	787.36±0.1	14.82±0.3	35.86±0.4	17.53±0.3
7 TM1	6.97±0.2	28.6±0.2	11.5±0.1	0.73±0.3	1.70±0.2	2.92±0.1	10±0.1	1.10±0.4	2.00±0.2	4.20±0.2	240.80±0.4	4.80±0.4	47.99±0.3	18.85±0.2
8 TM2	6.71±0.1	29.7±0.2	17.5±0.2	0.42±0.4	1.64±0.4	2.82±0.2	10±0.3	0.10±0.5	0.00±00	2.20±0.1	1612.31±0.3	0.86±0.3	85.10±0.2	36.70±0.3
9 TASR1	7.40±0.1	30.5±0.4	23±0.4	0.30±0.6	1.81±0.2	3.11±0.4	10±0.2	1.10±0.2	4.00±0.3	6.20±0.6	379.60±0.4	1.32±0.5	49.25±0.0	17.50±0.2
10TASR2	8.17±0.2	28.4±0.4	25.6±0.1	0.40±0.3	1.87±0.1	3.22±0.2	10±0.2	2.10±0.1	2.00±0.1	6.20±0.4	1073.5±0.3	0.49±0.3	36.45±0.1	51.40±0.3
WHO (mg/kg)	6.5-8.5	NA	0.5-3.0	3	500	<5	<5	6.5-8.0	30	2.8-4.5	250	200		
NESREA (mg/kg)	6.5-8.5	NA	NA	NA	NA	30	NA	6	40	NA	350	500		

Key: PGH – Poly Guest House; MO – MOWA; DL – Deeper Life; DR – Doma Road; OH – Omgbolo Hotel; TM – Telecom Mast (Gandu); NA – Not Available; TA – Tudun Abu (Shendam Road)

In Table 4, during the wet season, the concentrations of nitrates across the sampling points range from 131.36 mg/L of the first sampling point of Telecom Mast in Gandu to 1,312.15 mg/L of the first sampling point of MOWA in Bukan Sidi above the threshold limit of 30 mg/L. While in the dry season, the concentrations of nitrates across the sampling points range from 176.84 mg/L of the first sampling point of Doma Road to 1,755.21 mg/L of the first sampling point of Poly Guest House in Ombi II above the threshold limit of 30 mg/L. The high level of nitrates suggests high inputs of macro-nutrients of Nitrogen from refuse and run-off from nearby farmlands where fertilizers are applied (Beniah and Christian, 2020; Orodu and Morokowei, 2022).

In wet season, the concentrations of phosphates range from 0.12 mg/L of the first sampling point of Deeper Life to 7.86 mg/L of the first sampling point of Doma Road above the maximum permissible limit of 4.5 mg/L. During the dry season, the concentrations of phosphates range from 0.26 mg/L in the first sampling point of Deeper Life Church to 14.39 mg/L of the first sampling point of Doma Road above the maximum permissible limit of 4.5 mg/L. The high level of phosphates in these locations during the wet season is attributed to the run-off from farmlands from inhabitants who engage in agricultural activities using both natural and synthetic fertilizers. As a result, the refuse dumpsites close to these farmlands are prone to this high level of phosphates. Nitrogen, phosphorus and potassium are the most important primary nutrients in soil, while micronutrients such as Fe, Mn, Cu, Zn, and Ni are taken up by plants in their cationic forms (Beniah and Christian, 2020).

The concentrations of organic matter in these locations in wet season, range from 2.19% (w/w) of the first sampling point of Omgbolo Hotel to 3.24% (w/w) of the first sampling point of Poly Guest House. While in dry season, the concentrations of organic matter in these locations range from 2.82% (w/w) of the second sampling point of Gandu to 3.23% (w/w) of the first sampling point of Omgbolo Hotel and Poly Guest House. The moderately high concentration of organic matter provides information about the amount of decomposed plant and animal material in the soil which directly influence nutrient availability, water retention capacity, and microbial activity. This could be due to the presence of garden waste, food waste and high proportions of paper and packaging materials since more than half of the municipal waste consist of paper (Oluyemi *et al.,* 2008; Sani and Abba, 2012; Wodaje and Alemayehu, 2014).

However, the remaining results of other parameters obtained during the wet season are low and within WHO permissible level (Mekonnen *et al.,* 2020; Besufekad *et al*., 2020).

The physicochemical results obtained in wet season were generally higher during the dry season except for moisture content. This variation is due to evaporation and burning of waste (Oluyemi *et al,* 2008). The low moisture content suggests low amount of water available in soil owing to lack of rain water in dry season.

CONCLUSION

This study has established that in both wet and dry seasons, there were elevated concentrations of heavy metals (Mercury, Chromium, Manganese) in almost all locations exceeding the Local and International Soil Quality Guidelines. The pattern or trend is also similar with physicochemical parameters with high levels of Nitrates, Phosphates and Organic Matter above objectionable limit in almost all the locations.

RECOMMENDATIONS

The study therefore recommends the followings:

Appropriate government agencies and stakeholders should integrate the regular monitoring of waste disposal into its developmental plan and framework in order to mitigate excessive build-up of these metals in humans through the food chain.

Adequate measures should be put in place to create awareness on the ill effects arising from uncontrolled disposal of wastes to prevent harm to the environment and jeopardising our health.

There should be improvement on the dearth of data and general information on environmental sanitation at all levels of government to facilitate planning, monitoring and evaluation.

The knowledge of toxicity of heavy metals would educate the general public about the potential environmental risks associated with the use of refuse dumpsites for farming and consumption of plants within the area.

More studies should be carried out in these dumpsites to ascertain the potential ecological risks of other heavy metals not considered in this study.

Residents, policy makers and governments in the study area should embrace adequate sanitation strategies.

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