FULafia Journal of Science & Technology
ISSN (print) 2449-0954 \ ISSN (online) 2636-4972
https://lafiascijournals.org.ng/index.php/fjst
Sponsored By TERTIARY EDUCATION TRUST FUND
Manuscript => Received: Jan., 2024; **Accepted:** March, 2024; **Published:** April, 2024 https://doi.org/10.62050/fjst2024.v8n1.285

CORRELATION ANALYSIS AND MODELLING OF HEAVY METAL CONCENTRATIONS AND PHYSICOCHEMICAL PARAMETERS FROM SOIL SAMPLES OF FIVE SELECTED REFUSE DUMPSITES IN LAFIA LGA, NASARAWA STATE, NIGERIA

Solomon Joseph Anzene*, Timothy M. Akpomie and Matthew Olaleke Aremu
Department of Chemistry, Federal University of Lafia, PMB 146 Lafia, Nigeria *Corresponding email:
anzenejoe@yahoo.ca, solomonanzene63@gmail.com

ABSTRACT

Thousands of tons of solid wastes are generated and disposed daily in open dumps of most Nigerian cities due to rapid population explosion and commercial activities. 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 and dry seasons, the concentration of heavy metals, Hg, Cr, Mn were above that of World Health Organisation (WHO), and National Environmental Standards and Regulations Enforcement Agency (NESREA), while that of Pb, As, Fe, Zn, Cu and Ni were below the tolerable limits. The results for physicochemical parameters in wet and dry seasons for nitrates, phosphates and organic matter were above WHO standards. Statistical test at 0.05 probability level ($p < 0.05$) was used to determine the degree of association between pairs of the variables. The principal component analysis (PCA) was performed to measure the direct and inverse relationship between these parameters and heavy metal availability. Based on the different variables obtained at the study areas, a multiple linear regression analysis was determined from which a general linear model was formulated. The study recommends appropriate government agencies should as a matter of urgency integrate the regular monitoring of waste disposal into the state developmental plan and framework in order to prevent excessive build-up of these metals in humans through the food chain.

Keywords: Solid wastes, heavy metals, physicochemical parameters, principal components, linear model

INTRODUCTION

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. Effective control of the solid waste disposals has become one of the biggest challenges to the national and local authorities (Lekan *et al.*, 2020; Ngoc *et al.*, 2021). Dumping of solid wastes create environmental pollution related to toxins, leachate and greenhouse gases which are growing environmental concern.

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).

Heavy metals, sometimes called “trace elements” are described as those metals with specific gravity higher than 5 g/cm^3. They are stable elements that cannot be metabolized and are not biodegradable (Thelma *et al.*, 2020). 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 concentration. Some of these important heavy metals include Iron, Manganese, Copper, Zinc and Chromium among others. High concentration of essential metals in biological system could lead to toxicity on the exposed organisms. While 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 (Frances and Eleanor, 2003; Sylvester *et al.*, 2017).

Research yields data, and the flood of data generated by analytical instruments today produces large quantity of numbers, often complex to understand and quantify (Larry, 2009). In order to interpret such data sets, many computational methods have been designed to perform multivariate data analysis to reduce their dimensionality, so that most of the information in the data is understood and preserved. The evolution of personal computers allows faster acquisition, processing and interpretation of chemical data. Every scientist uses software designed to perform statistical analysis for better understanding of results. Chemometrics is a technique usually employed for this statistical analysis (Mendam *et al.*, 2000).

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 1991 census was 87,352 inhabitants and this has been projected to 133,782 by 1998 according to Lafia Master Plan. The study has further projected the population to 263,998 by 2010, and 315,550 by 2015 using the growth rate of 3.5% per annum with an average population density of 287 persons per square kilometer (Ebuga *et al.,* 2021). 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 astronomical 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, while open dumping of these solid wastes is a common practice (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 many of the nation and Africa's environment. Many heavy metals; Pb, Hg, As, Cd, Ba, Ag which are known poisons are also present in such 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). Physicochemical parameters of soil have been reported to have a profound influence on the mobility and bioavailability of heavy metals (Tukura *et al.*, 2007; Obasi *et al.*, 2012).

All soils naturally contain trace levels of metals and as a result, the occurrence of metals in soil is not pinpointing contamination. However, the concentration of metals in uncontaminated soil is most often associated with the geology of the parent substance from which the soil is formed. Generally, leachates contain toxic substances such as heavy metals and various organic pollutants which are likely to contaminate soil and ground water (Lawan *et al.*, 2012; Mochamad *et al.*, 2014).

In Nigeria, several studies have been carried out on the impact of wastes and other activities on soil, air and water quality (Sylvester *et al.*, 2017). Several pollution indices are available in literature for the assessment of environmental quality. Several authors have widely assessed pollution load and or contamination indices of heavy metals on environmental components using different load indices (Kabata-Pendias, 2011). Additionally, many studies have also focused on heavy metal concentration, distribution and source apportionment. These studies have used various chemical analytical techniques such as soil digestion, sequential extraction and studies mainly concentrated on the influences of anthropogenic activities. Others have explored the impact of different factors on the heavy metal accumulation and distribution patterns at the dumpsites (Adewuyi and Opasina, 2010; Torres-Bejarano *et al.*, 2019).

However, information on the chemometric assessment, such as pattern of distribution, or recognition, modeling (mathematical/regression equation), and forecasting of heavy metal concentration from waste dumpsites in Lafia Metropolis specifically and environs in particular is scanty or non-existent in literature. While the world is geared towards the fourth industrial revolution where artificial intelligence (AI), machine learning, augmented reality, internet of things (IOT), etc. is playing a major role, developing countries like Nigeria areyet to adopt, apply and test the efficiency of machine learning in the solid waste management (Anthony *et al.*, 2021).

The study determined the concentration of heavy metals and physicochemical parameters from selected soil samples in refuse-dumpsites in five geographical zones of Lafia Local Government Area. The study ascertained the level of contributions of composite parameters to the heavy metal concentrations using principal component Analysis (PCA), and developed a general multi-linear model to estimate the concentration of the respective heavy metals using the physicochemical parameters in the respective dumpsites.

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).

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, thermometer, pH meter, conductivity meter, Global Positioning System (GPS) device.

Description of the study area

The study area is Lafia Local Government Areawith 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 (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.

Methods

Sample collection

Soil samples (wastes) were collected at 0-15 cm below the top soil with the aid of soil Auger, from twenty (10 refuse dumpsites, and 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 five geographical locations or positions namely; Shabu, Ombi I, Bukan Sidi, Tudun Amba, Mararaba Akunza, and Tudun Abu. Each sampling unit from the refuse dumpsites was 50 m, 100 m apart and the controlwas 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 Metropolis	1. Shabu	2	2
2	Central part of Lafia Metropolis	2. Ombi I	2	2
3	Western part of Lafia Metropolis	3. TudunAmba	2	2
4	Southern part of Lafia Metropolis	4. MararabaAkunza	2	2
5	Eastern part of Lafia Metropolis	5. Tudun Abu	2	2
		Total	**10**	**10**

Sample preparation

Composite samples made by mixing individual sample units were put in 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 h, ground to pass through a 2 mm sieve to remove debris, gravel and other materials. Samples at 50, 100 m from each refuse dumpsites and control sites, 200 m 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 as shown in Table 2 (Vincent *et al.*, 2012; Nabil *et al.*, 2014; Ediene and Umoefok, 2017).

Table 2: Geographical positions of the soil samples taken from different locations of refuse dumpsites

S/N	Location	Northing	Easting	Altitude (m)
1	Shabu (Akurba Road)	451967	947331	175
2	Shabu (KofarMagajiMallam)	451975	947346	179
3	Ombi I (Transformer Street)	448576	945027	173
4	Ombi I (DD Hall)	448584	945014	172
5	TudunAmba (DOMA Road)	446778	938965	182
6	TudunAmba (DOMA Road)	446772	938964	187
7	M/Akunza (FULafia)	454698	936441	206
8	M/Akunza (FULafia)	454689	936449	206
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 (AOAC, 2013) standard methods. The pH, temperature were 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 were 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 min. 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±5°C for 4 h to obtain a constant weight (W_1). The measurement was done and the percentage moisture was calculated as follows:

$$\% \text{ Moisture} = \frac{(W_2 - W_1)}{W_1} x\, 100$$

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;

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

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 (Olayinka *et al.*, 2007)

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 h at 85°C in 12 mL of aqua regia (3:1 $HCl\text{-}HNO_3$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, As, Cd, Cr, Fe, Zn, Cu, Mn, Ni, using AAS (Oketola and Akpotu, 2013; Saida *et al.*, 2019).

Chemometric analysis and interpretation

The Principal Component Analysis, Correlation Analysis of the data were obtained using the Minitab-19 computer software package to ascertain the level of contributions of composite parameters to the heavy metal concentrations using principal component Analysis (PCA), and to develop a general multi-linear model to estimate the concentration of the respective heavy metals using the physicochemical parameters in the respective dumpsites.

RESULTS AND DISCUSSION

The results of the concentrations of heavy metals of soil samples and composting physicochemical parameters of soil samples from refuse dumpsites obtained in September 2021 for the wet season and March 2022 for the dry season in five geographical zones o Lafia Township and Environs are presented in Tables 3 – 6.

Table 3: Concentrations of heavy metals in soil samples from selected refuse dumpsites at different geographical locations in wet season

		Heavy Metals									
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	AKR1	0.105 ±0.041	0.414 ±0.037	0.151 ±0.086	0.672 ±0.037	0.336 ±0.093	0.346 ±0.066	0.775 ±0.105	0.809 ±0.095	0.065 ±0.022	0.307 ±0.033
2	KMM1	0.342 ±0.049	0.067 ±0.008	0.751 ±0.102	0.578 ±0.107	0.578 ±0.034	0.300 ±0.038	1.317 ±0.887	1.266 ±0.327	0.384 ±0.104	0.515 ±0.189
3	TS1	0.415 ±0.017	3.270 ±0.221	0.538 ±0.112	0.559 ±0.033	0.308 ±0.047	0.050 ±0.009	0.332 ±0.107	0.574 ±0.101	0.466 ±0.065	0.288 ±0.045
4	DDH1	0.772 ±0.184	0.586 ±0.108	0.654 ±0.056	0.496 ±0.190	0.159 ±0.072	0.125 ±0.097	0.324 ±0.064	0.652 ±0.234	0.534 ±0.214	0.741 ±0.201
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	FULTO1	0.142 ±0.033	0.071 ±0.083	0.000 ±0.000	0.428 ±0.521	0.165 ±0.062	0.000 ±0.000	0.217 ±0.062	1.354 ±0.520	0.615 ±0.078	1.025 ±0.083
8	FULTO2	0.000 ±0.000	0.129 ±0.072	0.236 ±0.061	0.264 ±0.084	0.403 ±0.041	0.038 ±0.031	0.273 ±0.083	0.651 ±0.078	0.517 ±0.062	0.574 ±0.078
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
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

AKR = AkurbaRoad; KMM = KofarMagajiMallam; TS = Transformer Street; DDH = DD Hall; DR = Doma Road; FULTO = Fed Univ of Lafia Take-Off Site; TASR = Tudun Abu (Shendam Road); NA = Not Available

Table 4: Concentrations of heavy metals in soil samples from selected refuse dumpsites at different geographical locations in dry season

S/N	Sample Code	Heavy Metals									
		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	AKR1	1.560	0.150	3.770	2.833	0.437	3.456	1.783	0.485	0.037	0.207
		±0.041	±0.037	±0.086	±0.037	±0.093	±0.066	±0.105	±0.095	±0.022	±0.033
2	KMM1	0.960	0.312	0.662	4.500	0.568	4.856	5.043	2.364	0.244	0.416
		±0.049	±0.008	±0.102	±0.107	±0.034	±0.038	±0.887	±0.327	±0.104	±0.189
3	TS1	0.160	2.160	0.392	4.433	0.359	2.529	0.232	3.091	0.567	0.367
		±0.017	±0.221	±0.112	±0.033	±0.047	±0.009	±0.107	±0.101	±0.065	±0.045
4	DDH1	0.160	0.431	1.068	4.500	0.376	4.147	0.425	2.309	0.435	0.642
		±0.184	±0.108	±0.056	±0.190	±0.072	±0.097	±0.064	±0.234	±0.214	±0.201
5	DR1	0.560	0.000	0.932	0.067	0.482	5.414	0.036	1.030	0.556	0.253
		±0.621	±0.000	±0.031	±0.218	±0.108	±0.084	±0.068	±0.021	±0.083	±0.069
6	DR2	0.670	0.000	0.527	0.167	0.563	2.292	0.043	2.970	0.768	1.106
		±0.219	±0.089	±0.068	±0.318	±0.109	±0.021	±0.010	±0.062	±0.083	±0.521
7	FULTO1	0.132	0.052	0.000	0.323	0.093	0.000	0.106	1.205	0.345	0.078
		±0.033	±0.083	±0.000	±0.521	±0.062	±0.000	±0.062	±0.520	±0.078	±0.083
8	FULTO2	0.096	0.110	0.132	0.132	0.526	0.003	0.142	0.542	0.418	0.360
		±0.000	±0.072	±0.061	±0.084	±0.041	±0.031	±0.083	±0.078	±0.062	±0.078
9	TASR1	0.425	0.123	0.000	0.108	0.276	0.223	0.253	0.843	0.318	1.362
		±0.078	±0.073	±0.000	±0.064	±0.085	±0.094	±0.082	±0.092	±0.072	±0.627
10	TASR2	0.216	0.345	0.020	0.326	0.176	0.216	0.268	0.946	0.346	0.174
		±0.085	±0.086	±0.094	±0.042	±0.072	±0.042	±0.087	±0.032	±0.055	±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

AKR = Akurba Road; KMM = KofarMagajiMallam; TS = Transformer Street; DDH = DD Hall; DR = Doma Road; FULTO = Fed Univ of Lafia Take-Off Site; TASR = Tudun Abu (Shendam Road); NA = Not Available

Table 5: Results of physicochemical parameters of soil samples from selected refuse dumpsites at different geographical locations in wet season

Sample Code	Physicochemical Parameters													
	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 AKR1	6.8	27.9	74.0	9.69	1.81	3.13	40	1.60	4.20	6.4	7.14	0.58	21.27	27.60
	±0.3	±0.4	±0.0	±0.1	±0.8	±0.2	±0.0	±0.4	±0.8	±0.9	±0.9	±0.6	±0.8	±0.0
2KMM1	7.7	28.8	57.3	15.84	1.77	3.07	34	2.10	2.40	4.7	1280.00	7.21	14.18	14.35
	±0.5	±0.1	±0.3	±0.4	±0.1	±0.8	±0.4	±0.2	±0.5	±0.0	±0.8	±0.4	±0.0	±0.6
3 TS1	7.5	28.7	93.6	4.12	1.78	3.08	30.0	1.30	4.20	6.0	2731.15	0.09	7.28	35.42
	±0.0	±0.3	±0.8	±0.5	±0.1	±0.3	±0.4	±0.2	±0.3	±0.7	±0.3	±0.4	±0.2	±0.8
4 DDH1	7.7	28.3	47.3	4.11	1.78	3.10	40.0	1.21	1.80	3.1	934.30	0.21	14.08	8.50
	±0.8	±0.1	±0.4	±0.9	±0.5	±0.4	±0.2	±0.3	±0.1	±0.4	±0.0	±0.1	±0.1	±0.2
5 DR1	7.08	28.5	55.5	11.85	1.82	3.13	40.0	2.01	2.00	5.1	736.21	7.86	14.18	14.06
	±0.3	±0.4	±0.6	±0.3	±0.8	±0.5	±0.6	±0.7	±0.6	±0.2	±0.9	±0.6	±0.3	±0.1
6 DR2	6.39	28.6	28.8	6.37	1.80	3.12	20.0	1.20	3.2	5.5	731.01	7.80	35.45	11.20
	±0.6	±0.3	±0.1	±0.4	±0.2	±0.2	±0.2	±0.3	±0.3	±0.5	±0.6	±0.6	±0.5	±0.4
7 FULTO1	6.70	28.6	45.7	8.57	1.89	3.24	80.0	2.00	2.40	4.80	978.21	1.26	7.09	10.26
	±0.4	±0.7	±0.1	±0.1	±0.8	±0.6	±0.5	±0.9	±0.1	±0.2	±0.6	±0.9	±0.4	±0.2
8 FULTO2	5.08	27.6	24.9	8.15	1.72	2.96	10.0	2.30	3.20	5.40	721.30	2.31	35.14	9.25
	±0.8	±0.2	±0.2	±0.7	±0.8	±0.3	±0.4	±0.1	±0.6	±0.2	±0.4	±0.6	±0.1	±0.6
9 TASR1	6.86	28.6	46.00	3.21	1.82	3.14	24.42	2.01	3.20	5.60	936.70	0.31	30.28	11.21
	±0.5	±0.6	±0.8	±0.1	±0.5	±0.4	±0.4	±0.2	±0.7	±0.4	±0.6	±0.3	±0.5	±0.1
10 TASR2	7.90	29.5	30.40	3.50	1.80	3.10	14.48	2.30	2.40	5.70	946.31	2.96	7.09	10.26
	±0.0	±0.1	±0.2	±0.3	±0.2	±0.2	±0.2	±0.6	±0.8	±0.7	±0.5	±0.8	±0.8	±0.4
WHO(mg/kg)	6.5-8.5	NA	1400	21-40	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	NA	NA	30	NA	6	40	NA	350	500

AKR = Akurba Road; KMM = KofarMagajiMallam; TS = Transformer Street; DDH = DD Hall; DR = Doma Road; FULTO = Fed Univ of Lafia Take-Off Site; TASR = Tudun Abu (Shendam Road); NA = Not Available

Table 6: Results of physicochemical parameters of soil samples from selected refuse dumpsites at different geographical locations in dry season

Sample Code	Physicochemical Parameters													
	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 AKR1	7.26	28.2	*325*	0.52	1.78	3.05	160	1.20	4.00	6.20	1040	0.87	77.99	47.80
	±0.2	±0.3	±0.0	±0.1	±0.7	±0.1	±0.1	±0.4	±0.7	±0.6	±0.6	±0.4	±0.6	±0.1
2 KMM1	7.79	27.5	196.7	0.61	1.88	3.23	170	2. 20	2.00	4.20	2745.26	14.39	42.54	24.02
	±0.3	±0.1	±0.2	±0.6	±0.1	±0.6	±0.3	±0.3	±0.3	±0.2	±0.3	±0.2	±0.0	±0.4
3 TS1	5.03	32.6	9.00 ±0.6	0.28	1.76	3.03	480	2.20	2.00	6.20	3797.89	0.17	85.08	51.53
	±0.4	±±0.3		±0.4	±0.1	±0.4	±0.0	±0.2	±0.2	±0.4	±0.2	±0.3	±0.1	±0.6
4 DDH1	8.99	32.4	47.0	0.37	1.78	3.05	40	1.10	2.00	4.20	1082.10	0.45	42.54	19.26
	±0.6	±0.6	±0.6	±0.3	±0.4	±0.6	±0.4	±0.3	±0.3	±0.4	±0.0	±0.2	±0.6	±0.3
5 DR1	8.88	38.9	39.8	0.61	1.78	3.05	20	1.10	2.00	4.20	176.84	14.39	42.56	24.82
	±0.4	±0.6	±0.1	±0.1	±0.4	±0.1	±0.4	±0.1	±0.4	±0.3	±0.6	±0.1	±0.3	±0.2
6 DR2	8.32	39.7	60	0.84	1.82	3.13	30	2.10	4.00	6.20	787.36	14.82	35.86	17.53
	±0.2	±0.4	±0.2	±0.2	±0.1	±0.3	±0.2	±0.3	±0.5	±0.2	±0.1	±0.3	±0.4	±0.3
7 FULTO1	8.06	28.9	64.4	0.70	1.88	3.23	30	2.10	4.00	6.20	1448	3.48	49.60	19.45
	±0.1	±0.4	±0.4	±0.4	±0.3	±0.3	±0.4	±0.6	±04	±0.6	±0.7	±0.4	±0.2	±0.2
8 FULTO2	5.43	30.0	28.9	0.72	1.60	2.75	10	0.10	0.00	2.20	1103.5	1.72	35.50	19.30
	±0.3	±0.5	±0.5	±0.6	±0.4	±0.4	±0.3	±0.1	±0.0	±0.3	±0.6	±0.3	±0.3	±0.4
9 TASR1	7.40	30.5	23	0.30	1.81	3.11	10	1.10	4.00	6.20	379.60	1.32	49.25	17.50
	±0.1	±0.4	±0.4	±0.6	±0.2	±0.4	±0.2	±0.2	±0.3	±0.6	±0.4	±0.5	±0.0	±0.2
10 TASR2	8.17	28.4	25.6	0.40	1.87	3.22	10	2.10	2.00	6.20	1073.5	0.49	36.45	51.40
	±0.2	±0.4	±0.1	±0.3	±0.1	±0.2	±0.2	±0.1	±0.1	±0.4	±0.3	±0.3	±0.1	±0.3
WHO (mg/kg)	6.5-8.5	NA	1400	21-40	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	NA	NA	30	NA	6	40	NA	350	500

AKR = Akurba Road; KMM = KofarMagajiMallam; TS = Transformer Street; DDH = DD Hall; DR = Doma Road; FULTO = Fed Univ of Lafia Take-Off Site; TASR = Tudun Abu (Shendam Road); NA = Not Available

Table 3 showed the results of concentration of heavy metals across the sampling units in Shabu in wet season. 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). The concentrations of Hg across the sampling units ranged from 0.051 mg/kg in the second sampling point of KofarMagajiMallam which is 100 m away from the refuse dumpsite to 0.414 mg/kg in the first sampling point of Akurba Road (50 m from refuse dumpsite). The concentrations observed for Hg were above the WHO of 0.04 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) range from 0.302 mg/kg in the second sampling point of Akurba Road to 0.672 mg/kg of the first sampling point of Akurba Road above the maximum threshold limit of 0.002-0.2 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). The concentrations of Manganese (Mn) range from 0.694 mg/kg of the second sampling point of KofarMagajiMallam to 1.266 mg/kg of the first sampling point of KofarMagajiMallam 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).

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 4 showed the results of concentration of heavy metals across the sampling units in Shabu in dry season. 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). The concentrations of Hg across the sampling units range from 0.006 mg/kg of the second sampling points of KofarMagajiMallam to

0.317 mg/kg of the second sampling point of Akurba Road. The concentrations observed for Hg were above the WHO threshold limit of 0.04 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 concentrations of Chromium (Cr) range from 2.800 mg/kg in the first sampling point of Akurba Road to 4.533 mg/kg of the second sampling point of KofarMagajiMallam 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).

The concentrations of Manganese (Mn) range from 0.667 mg/kg of the second sampling point of Akurba Road to 2.364 mg/kg of the first sampling point of KofarMagajiMallam 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).

In Table 5, the concentrations of nitrates across the sampling points in Shabu range from 7.14 mg/L in the first sampling point of Akurba Road to 1,280 mg/L of the first sampling point of KofarMagajiMallam above the threshold limit of 30 mg/L. The high level of nitrates suggests high inputs of macro-nutrients of Nitrogen, Phosphorus from refuse and run-off from nearby farmlands where fertilizers are applied (Beniah and Christian, 2020; Orodu and Morokowei, 2022).

The concentrations of phosphates range from 0.20 mg/L in the second sampling point of Akurba Road to 7.25 mg/L of the second sampling point of KofarMagajiMallam 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).

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

In Table 6, the concentrations of nitrates across the sampling points in Shabu range from 492.63 mg/L in the second sampling point of KofarMagajiMallam to 2,745.26 mg/L of the first sampling point of KofarMagajiMallam above the threshold limit of 30 mg/L. The high level of nitrates suggests high inputs of macro-nutrients of Nitrogen, Phosphorus from refuse and run-off from nearby farmlands where fertilizers are applied (Beniah and Christian, 2020; Orodu and Morokowei, 2022).

The concentrations of phosphates range from 0.35 mg/L in the second sampling point of Akurba Road to 14.39 mg/L of the second sampling point of KofarMagajiMallam 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 range from 3.05% (w/w) of the first sampling point of Akurba Road to 3.23% (w/w) of both the second sampling point of Akurba Road and the first sampling point of KofarMagajiMallam. 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 other parameters obtained during the wet season are low and within WHO permissible level (Mekonnen *et al.*, 2020; Besufekad *et al*., 2020).

Table 7a: Correlation matrix of some heavy metals and selected physicochemical parameters in Shabu for wet season

Para.	Pb	Hg	As	Cr	Fe	Zn	Cu	Mn	Ni	B	pH
Hg	-0.627										
	0.258										
As	-0.343	-0.390									
	0.572	0.517									
Cr	-0.186	0.724	-0.224								
	0.765	0.166	0.717								
Fe	-0.322	-0.199	0.931	0.133							
	0.597	0.748	0.022	0.831							
Zn	-0.976	0.529	0.517	0.212	0.520						
	0.004	0.360	0.372	0.733	0.369						
Cu	0.902	-0.477	-0.176	0.170	-0.018	-0.814					
	0.036	0.417	0.777	0.785	0.977	0.094					
Mn	-0.423	-0.441	0.863	-0.610	0.625	0.515	-0.472				
	0.478	0.458	0.060	0.274	0.259	0.375	0.422				
Ni	0.926	-0.636	-0.064	-0.006	0.035	-0.825	0.981	-0.315			
	0.024	0.248	0.919	0.992	0.956	0.085	0.003	0.606			
B	0.962	-0.389	-0.547	0.030	-0.458	-0.970	0.895	-0.655	0.867		
	0.009	0.517	0.340	0.962	0.438	0.006	0.040	0.230	0.057		
pH	0.090	-0.290	0.695	0.305	0.864	0.121	0.434	0.261	0.450	-0.004	
	0.886	0.636	0.193	0.618	0.059	0.847	0.465	0.672	0.447	0.994	
Temp	-0.501	-0.221	0.923	-0.196	0.843	0.641	-0.358	0.846	-0.261	-0.674	0.480
	0.389	0.721	0.025	0.753	0.073	0.244	0.554	0.071	0.672	0.212	0.413
MC	0.169	-0.376	0.584	0.119	0.683	0.005	0.406	0.263	0.443	0.061	0.655
	0.786	0.533	0.301	0.849	0.204	0.993	0.498	0.670	0.455	0.922	0.230
OC	-0.988	0.731	0.209	0.274	0.217	0.943	-0.890	0.288	-0.938	-0.911	-0.156
	0.002	0.161	0.736	0.655	0.726	0.016	0.043	0.639	0.018	0.032	0.803
PO_4^{2-}	0.832	-0.520	-0.015	0.153	0.138	-0.716	0.964	-0.339	0.960	0.796	0.507
	0.080	0.369	0.981	0.806	0.825	0.174	0.008	0.577	0.009	0.107	0.383
SO_4^{2-}	-0.751	0.897	-0.074	0.671	0.099	0.708	-0.543	-0.173	-0.670	-0.574	-0.005
	0.143	0.039	0.906	0.215	0.874	0.181	0.345	0.781	0.216	0.312	0.994

Table 7b

parameter	Temp	MC	OC	PO_4^{2-}
MC	0.639			
	0.246			
OC	0.369	-0.267		
	0.541	0.664		
PO_4^{2-}	-0.138	0.627	-0.849	
	0.825	0.257	0.069	
SO_4^{2-}	-0.033	-0.387	0.828	-0.604
	0.958	0.520	0.083	0.281

Cell Contents: Pearson correlation
P-Value

Table 8a: Correlation matrix of some heavy metals and selected physicochemical parameters in Shabu for dry season

Para.	Pb	Hg	As	Cr	Fe	Zn	Cu	Mn	Ni	B	pH
Hg	0.553										
	0.334										
As	0.843	0.052									
	0.073	0.933									
Cr	-0.947	-0.307	0.888								
	0.014	0.615	0.044								
Fe	0.416	0.955	-0.026	-0.118							
	0.486	0.011	0.967	0.850							
Zn	-0.309	0.447	-0.504	0.597	0.674						
	0.613	0.451	0.386	0.288	0.212						
Cu	0.479	0.993	-0.048	-0.243	0.936	0.447					
	0.414	0.001	0.939	0.694	0.019	0.450					
Mn	-0.861	-0.090	-0.912	0.975	0.101	0.735	-0.026				
	0.061	0.886	0.031	0.005	0.872	0.157	0.967				
Ni	-0.982	-0.690	-0.753	0.873	-0.579	0.135	-0.619	0.750			
	0.003	0.197	0.141	0.054	0.306	0.829	0.265	0.144			
B	0.432	0.958	-0.011	-0.136	1.000	0.662	0.939	0.083	-0.593		
	0.468	0.010	0.986	0.828	0.000	0.224	0.018	0.894	0.292		
pH	0.033	0.303	0.054	0.234	0.559	0.803	0.232	0.327	-0.153	0.554	
	0.958	0.620	0.931	0.705	0.327	0.102	0.707	0.591	0.806	0.333	
Temp	0.503	0.197	0.292	-0.662	-0.102	-0.739	0.232	-0.657	-0.422	-0.090	-0.823
	0.388	0.750	0.633	0.224	0.871	0.154	0.708	0.228	0.479	0.886	0.087
MC	0.358	0.379	0.004	-0.452	0.099	-0.490	0.441	-0.397	-0.332	0.107	-0.766
	0.554	0.529	0.995	0.445	0.874	0.402	0.457	0.509	0.586	0.864	0.131
OC	-0.476	0.301	-0.854	0.522	0.244	0.316	0.413	0.607	0.384	0.234	-0.310
	0.418	0.622	0.065	0.367	0.693	0.605	0.490	0.278	0.524	0.704	0.611
PO_4^{2-}	-0.943	-0.301	-0.882	1.000	-0.108	0.609	-0.239	0.977	0.866	-0.126	0.252
	0.016	0.622	0.048	0.000	0.862	0.276	0.698	0.004	0.058	0.840	0.683
SO_4^{2-}	0.579	-0.013	0.835	-0.519	0.080	-0.053	-0.134	-0.535	-0.543	0.089	0.549
	0.307	0.983	0.079	0.370	0.899	0.933	0.829	0.352	0.344	0.887	0.338

Table 8b

parameter	Temp	MC	OC	PO_4^{2-}
MC	0.939			
	0.018			
OC	0.177	0.487		
	0.776	0.406		
PO_4^{2-}	-0.675	-0.466	0.512	
	0.211	0.429	0.377	
SO_4^{2-}	-0.281	-0.525	-0.945	-0.505
	0.647	0.363	0.015	0.385

Cell Contents: Pearson correlation
P-Value

Correlation matrix between some heavy metals and selected physicochemical parameters in wet and dry season

In order to quantify the relationships between the concentrations of heavy metals and physicochemical parameters, a correlation matrix was performed on the dataset. The correlation matrix represents the relationships between pairs of variables in a dataset. High correlations (r = 1, or r > 1) indicates a perfect relationship or very strong relationship to each other in terms of strength and direction. Whereas P-values ($P<0.05$) assess the significance of the relationships between the values. A low P-value suggests that the observed correlation is unlikely to have occurred by chance, or indicating a statistically significant relationship between the variables. Conversely, a high P-value suggests that the observed correlation could indicate a lack of statistical significance (Ibe *et al.*, 2020).

Across the locations during the wet seasons, the correlation analysis between some pairs of the variables between heavy metals and physicochemical parameters are summarized as in Table 9.

High positive correlations (r > 0.5) were noticed among pairs of variables in some of the locations such as Ombi I (r = 0.913, pH/Pb, $P < 0.05$), TudunAmba (r

= 0.817, Ph/Pb; r = 0.509, Temp/Hg), MararabaAkunza (r = 0.812, Temp/Hg, r =0.887, Cr/Fe), however, insignificant (P < 0.05), and significant (P >0.05). The observed strong positive correlations is an indication that an increase in the concentration of one of the pairs of the variable affects the other positive, for example an increase in the concentration of physicochemical parameter obtained in the dumpsites result in increase in the concentration of the heavy metals (Ibe *et al.*, 2020).

On the other hand, high negative correlations were observed in TudunAmba (r = -0.953, P < 0.05, Cr/Fe), Tudun Abu (r = -0.953, P >0.05, Cr/Fe), Ombi I (r = -0.568, P > 0.05, Cr/Fe). The correlation coefficients measured between these pairs of variables are strong and negative, which showed that an increase in the concentration in one of the pairs will result in decrease in the concentration of the other (Ogundiran and Afolabi, 2008; Olukoya *et al.*, 2019).

The strong significant correlation buttresses the fact that most common heavy metals are major components of refuse dumpsites, therefore indicating a common source (Ganiyu *et al.,* 2016; Lekan *et al.,* 2020).

The degree of linear association between pH, temperature and other parameters measured by correlation coefficients indicate that correlation among these parameters are generally strong (r>0.5) and non-significant. However, some of the parameters are inversely correlated. pH for instance correlated negatively with Pb, and the negative correlation coefficient with this heavy metal showed that higher concentration of heavy metals are mostly found in places with low pH or acidic conditions where they become highly soluble (Nabil *et al.,* 2014).

Table 9: Correlation matrix between some pairs of heavy metals and selected physicochemical parameters in wet season

Dumpsites/ Parameters	Correlation Coefficient	P-Value	Comment
Shabu			
pH/Pb	0.090	0.886	Low positive correlation/insignificant
Temp/Hg	- 0.221	0.721	Low positive correlation/insignificant
Cr/Fe	0.133	0.831	Low positive correlation/insignificant
Ombi I			
pH/Pb	0.913	0.030	Very strong positive correlation/significant
Temp/Hg	0.369	0.541	Low positive correlation/insignificant
Cr/Fe	- 0.568	0.318	Strong negative correlation/insignificant
TudunAmba			
pH/Pb	0.817	0.183	Very strong positive correlation/insignificant
Temp/Hg	0.509	0.491	Strong positive correlation/insignificant
Cr/Fe	- 0.953	0.047	Very strong negative correlation/significant
MararabaAkunza			
pH/Pb	0.125	0.875	Low positive correlation/insignificant
Temp/Hg	- 0.782	0.218	Very strong negative correlation/insignificant
Cr/Fe	0.502	0.498	Strong positive correlation/insignificant
Tudun Abu			
pH/Pb	- 0.835	0.165	Very strong negative correlation/insignificant
Temp/Hg	0.812	0.188	Very strong positive correlation/insignificant
Cr/Fe	0.887	0.113	Very strong positive correlation/insignificant

Perfect = 1, Very Strong = 0.75, Strong = 0.5, Moderate = 0.3, Weak = 0.1 + for positive correlation, - for negative correlation.

P-Value <0.05 Significant, P-Value >0.05 Insignificant

Table 10: Correlation matrix between some pairs of heavy metals and selected physicochemical parameters in dry season

Dumpsites/ Parameters	Correlation Coefficient	P-Value	Comment
Shabu			
pH/Pb	0.033	0.958	Low positive correlation/insignificant
Temp/Hg	0.197	0.750	Low positive correlation/insignificant
Cr/Fe	- 0.118	0.850	Low negative correlation/insignificant
Ombi I			
pH/Pb	- 0.054	0.931	Low negative correlation/insignificant
Temp/Hg	- 0.257	0.676	Low negative correlation/insignificant
Cr/Fe	0.753	0.142	Very strong positive correlation/insignificant
TudunAmba			
pH/Pb	- 0.998	0.002	Very strong negative correlation/significant
Temp/Hg	- 0.968	0.062	Very strong negative correlation/insignificant
Cr/Fe	0.818	0.182	Very strong positive correlation/insignificant
MararabaAkunza			
pH/Pb	- 0.538	0.462	Strong negative correlation/insignificant
Temp/Hg	- 0.556	0.444	Strong negative correlation/insignificant
Cr/Fe	- 0.173	0.827	Low negative correlation/insignificant
Tudun Abu			
pH/Pb	- 0.898	0.102	Very strong negative correlation/insignificant
Temp/Hg	- 0.747	0.253	Very strong negative correlation/insignificant
Cr/Fe	0.866	0.134	Very strong positive correlation/insignificant

The correlation analysis of the data obtained for some heavy metals and physicochemical parameters in dry season between some pairs of variables are presented in Table 10.

The degree of association between pH, Temperature against Pb, Hg for example at different locations for Dry Season, indicate strong negative correlation in TudunAmba (r = -0.998, P < 0.05, for pH/Pb; r = -0.968, P > 0.05 for Temp/Hg), MararabaAkunza (r = -0. 538, P > 0.05 for pH/Pb; r = -0.556, P > 0.05 for Temp/Hg), Tudun Abu (r = -0.898, P > 0.05, for pH/Pb; r = -0.747, P > 0.05 for Temp/Hg). The degree of association could be attributed to the influence of high temperature in dry season over other parameters (Nabil *et al.*, 2014). On the other hand, the degree of the effect of pH, temperature on some other parameters is strong positive and insignificant. This indicates that increase in pH, Temperature will only yield insignificant increase with the other parameters.

However, the pairs of Cr/Fe in Tudun Abu, TudunAmba, Ombi I (r = 0.866, P > 0.05; r = 0.818, P > 0.05; r = 0.753, P > 0.05) correlated positively.

The results of pair of Cr/Fe indicate that parameters within the locations are strong, and an increase in concentration of one of the variable will result in increase in the other (Ruth *et al.*, 2021).

Table 11a: Principal component analysis in relation to level of contributions of composite parameters to the heavy metal concentrations in Shabu wet and dry seasons

Results for Shabu wet season (Eigen analysis of the correlation matrix)

Parameter	pH	Temp.	MC	OC	OM	COD	BOD	DO	PO_4^{2-}	Cl^-	SO_4^{2-}
Eigen value	4.7481	2.6811	2.2663	1.3046	0.0000	0.0000	0.0000	-0.0000	-0.0000	-0.0000	-0.0000
Proportion	0.432	0.244	0.206	0.119	0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000
Cumulative	0.432	0.675	0.881	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 11b

Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
pH	-0.173	-0.057	0.593	0.199	-0.285	0.214	0.059	-0.334	0.062	0.514	0.256
Temp	0.028	0.419	0.459	-0.189	-0.013	0.069	0.535	-0.069	0.070	-0.362	-0.381
MC	-0.282	0.356	0.315	0.210	0.062	0.014	-0.612	0.406	0.278	-0.102	-0.137
OC	0.424	0.175	0.140	0.124	0.035	0.089	-0.431	-0.376	-0.600	-0.071	-0.233
OM	0.411	0.066	0.273	0.120	-0.017	-0.059	0.185	0.605	-0.309	-0.035	0.488
COD	-0.355	0.177	-0.125	0.464	0.243	-0.283	0.298	0.133	-0.387	0.361	-0.292
BOD	0.206	0.515	-0.197	-0.031	-0.472	-0.574	-0.038	-0.149	0.185	0.170	0.118
DO	0.099	0.312	-0.400	0.503	-0.204	0.613	0.147	-0.018	0.136	-0.122	0.087
PO_4^{2-}	-0.435	-0.066	0.055	0.251	-0.129	-0.248	-0.002	-0.264	-0.219	-0.624	0.393
Cl^-	0.174	-0.501	0.096	0.352	-0.538	-0.157	0.025	0.187	0.078	-0.140	-0.459
SO_4^{2-}	0.378	-0.099	0.131	0.442	0.533	-0.257	0.062	-0.260	0.450	-0.071	0.078

Table 12a: Results for Shabu dry season (Eigen analysis of the correlation matrix)

Parameter	pH	Temp.	MC	OC	OM	COD	BOD	DO	PO_4^{2-}	Cl^-	SO_4^{2-}
Eigenvalue	6.1784	3.2407	1.5809	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0000	-0.0000	-0.0000
Proportion	0.562	0.295	0.144	0.000	0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000
Cumulative	0.562	0.856	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 12b

Variable	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11
pH	-0.192	-0.292	0.561	-0.160	-0.058	0.100	0.225	-0.238	0.606	0.189	-0.124
Temp	0.157	0.493	-0.192	-0.217	-0.239	-0.065	-0.080	-0.751	0.127	0.016	0.002
MC	0.268	0.412	-0.067	0.521	-0.064	0.023	0.324	0.237	0.296	0.479	0.003
OC	0.392	-0.118	0.049	-0.019	-0.408	0.702	0.048	0.028	-0.180	-0.111	-0.349
OM	0.391	-0.128	0.016	-0.217	-0.490	-0.230	-0.197	0.306	0.319	-0.144	0.485
COD	0.383	-0.149	0.119	0.035	-0.007	-0.502	0.601	-0.116	-0.188	-0.315	-0.235
BOD	-0.277	-0.291	-0.397	0.493	-0.351	-0.163	-0.166	-0.102	0.295	-0.243	-0.320
DO	-0.265	-0.088	-0.585	-0.409	-0.072	0.179	0.572	0.123	0.119	0.047	0.130
PO_4^{2-}	0.132	-0.521	-0.095	0.290	-0.019	0.082	0.070	-0.419	-0.265	0.360	0.482
Cl^-	-0.321	0.277	0.271	0.322	-0.158	0.238	0.272	-0.067	-0.060	-0.520	0.458
SO_4^{2-}	-0.381	0.096	0.212	-0.096	-0.612	-0.256	0.051	0.103	-0.430	0.375	-0.107

Principal component analysis of heavy metal concentrations and physicochemical parameters in wet and dry seasons

The principal component analysis (PCA) was performed to transform the original variables into principal components, and to calculate the Eigen values, proportion of variance, and cumulative variance.

With reference to Shabu, in wet season, the variances in the variables were accounted for by PC1, PC2, PC3 and PC4 with Eigen values of 4.75, 2.68, 2.27 and 1.31, respectively. PC1, PC2, PC3 and PC4 accounted for 43.2, 24.4, 20.6 and 11.9% of the variance, respectively.

PC1 had a significant positive association with OC, OM and significant negative association with PO_4^{2-}. PC2 recorded significant positive association with BOD and significant negative association with Cl^-. Similarly, PC3 recorded a significant positive association with pH and significant negative association DO.

With reference to Shabu in dry season, the variances in the variables were accounted for, by PC1, PC2 and PC3 with Eigen values of 6.18, 3.24 and 1.58, respectively. PC1, PC2 and PC3 accounted for 56.2, 29.5 and 14.4% of the variance, respectively.

PC1 had a large positive association with OC, OM and COD and large negative association with Cl^- and SO_4^{2-}. PC2 recorded large positive association with Temp, MC, but negative association with PO_4^{2-}. Similarly, PC3 recorded a significant positive association with pH and significant negative association with DO.

In the central geographical location of Ombi I, wet season, the variance in the variables were accounted for by PC1, PC2 and PC3 with Eigen values of 4.55, 3.58 and 2.87, respectively. PC1, PC2 and PC3 account for 41.4, 32.6 and 26.1% of the variance, respectively.

PC1 had a significant positive association with OC, OM, COD and insignificant negative association with SO_4^{2-}. PC2 recorded significant positive association with Temp, BOD and significant negative association with PO_4^{2-}. The pattern is similar across the geographical locations of the Local Government Area.

The principal components measure the direct and inverse relationship between these parameters and heavy metal availability and abundance in the soil (Adamu, and Ahmad, 2012; Amadi and Nwankwoala, 2013; Olukoya *et al.*, 2019).

The association of the variables with principal components account for their contributions to heavy metal concentrations in the soil and the direction of the association (negative/positive). Narrowing down to the variables, the ones with higher coefficients account for most part of the variance and their contributions to heavy metal concentrations (Iwegbue *et al.*, 2007; Anake *et al.*, 2009; Ruben *et al.*, 2015; Ibe *et al.*, 2020; Johnbosco and Chukwuma, 2020; Carol and Michael, 2021; Daniel *et al.*, 2022).

Development of a general linear model to quantify the relationships between the concentration of heavy metals and the different composite parameters in refuse dumpsites

Using the Multiple linear regression analysis (MLR) model, a regression equation was developed to quantify the relationship between the concentration of heavy metals and the composite parameters to account for the variation of the independent variables to the dependent variable (Adamu and Ahmad, 2012; Roseline *et al.*, 2020; Smita *et al.*, 2020). The regression model was developed in line with the following prediction equation:

$$Y = \beta_O + \beta_1 X_1 + \beta_2 X_2 \ldots\ldots. + \beta_n X_n + \varepsilon$$

Y = dependent variable
X_1, X_2 = independent variables
β_O = intercept
β_1, β_2 = regression parameters
ε = error

Hence from the correlation or covariance coefficients generated from the data set, the following regression models were obtained for each of the metal.

Regression Equation for Pb

Pb = -1.73 + 0.030 pH - 0.0155 Temp + 0.306 MC + 0.93 OC - 0.0126 PO_4^{2-} + 0.0296 SO_4^{2-}

Regression equation for Hg

Hg = 1.201 + 0.0401 pH - 0.01463 Temp + 0.0603 MC - 0.495 OC - 0.00086 PO_4^{2-} - 0.00110 SO_4^{2-}

Regression equation for As

As = 6.43 + 0.201 pH - 0.0680 Temp + 0.170 MC - 2.95 OC - 0.0523 PO_4^{2-} + 0.0468 SO_4^{2-}

Regression equation for Cr

Cr = 3.20 - 0.029 pH - 0.142 Temp - 0.523 MC + 1.68 OC + 0.1082 PO_4^{2-} + 0.0253 SO_4^{2-}

Regression equation for Fe

Fe = 1.078 - 0.0288 pH + 0.0263 Temp + 0.0169 MC - 0.644 OC + 0.00489 PO_4^{2-} - 0.00340 SO_4^{2-}

Regression equation for Zn

Zn = -2.09 + 0.073 pH + 0.012 Temp + 0.211 MC + 2.01 OC + 0.0546 PO_4^{2-} + 0.0411 SO_4^{2-}

Regression equation for Cu

Cu = 1.14 + 0.218 pH - 0.276 Temp + 0.653 MC + 3.58 OC - 0.0323 PO_4^{2-} + 0.0214 SO_4^{2-}

Regression equation for Mn

Mn = -11.78 + 1.578 pH - 0.1070 Temp + 0.221 MC + 3.90 OC - 0.0517 PO_4^{2-} - 0.0504 SO_4^{2-}

Regression equation for Ni

Ni = -0.39 + 0.1267 pH - 0.0025 Temp - 0.0604 MC - 0.017 OC + 0.01048 PO_4^{2-} - 0.00231 SO_4^{2-}

Regression equation for B

B = -0.99 + 0.1431 pH - 0.0012 Temp - 0.1031 MC + 0.405 OC - 0.00869 PO_4^{2-} - 0.00618 SO_4^{2-}

Summary

The study evaluated the concentrations of ten (10) heavy metals across twenty (20) selected refuse dumpsites in Lafia Local Government Area. Fourteen (14) physicochemical parameters of the soil samples from the refuse dumpsites were also investigated in the wet and dry seasons. 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 metal ranged from Hg (0.027-3.270), Cr (0.062-1.075), and Mn (0.074-1.656) mg/kg were above the maximum permissible limits of (0.04), (0.2), (0.1) mg/kg respectively for each metal by World Health Organisation (WHO), and (0.0005 mg/kg) 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 (0.003-2.160), Cr (0.067-4.533), and Mn (0.084-5.697) mg/kg across the locations were also found to be above the tolerable limits. The levels of nitrates in wet season (7.14 – 2731.15 mg/L), phosphates (0.12 – 14.85 mg/L) and organic matter (2.19 – 3.22% w/w), and dry season, nitrates(176.14 – 3797.89 mg/L), phosphates (0.17 mg/L-14.85 mg/L) and organic matter (1.64 – 3.23% w/w), were above WHO standards of 30, 4.5 mg/L and 3% w/w respectively, while other results obtained for physicochemical parameters during the wet and dry 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. Statistical test at 0.05 probability level ($p < 0.05$) was used to determine the degree of association between the pairs of variables. The results between selected physicochemical parameters and some heavy metals are strong positively ($r > 0.5$) and non-significant, while some are negative. The principal component analysis (PCA) was performed to transform the original variables into principal components, and to calculate the Eigen values, proportion of variance, and cumulative variance. The principal components measure the direct and inverse relationship between these parameters and heavy metal availability and abundance in the soil. Based on the different variables obtained at the study areas, a multiple linear regression analysis was determined from which a general linear model was formulated to predict an outcome variable from predictive variable.

Conclusion and Recommendation

The research assessed chemometrically, the concentration of heavy metals and physicochemical parameters from selected soil samples in refuse-dumpsites in Lafia Local Government Area. Concentrations of heavy metals in soil samples from selected ~~w~~aste dumpsites were determined and the results indicated high concentrations of Hg, Cr and Mn above the threshold limit of WHO, and NESREA. In the case of physicochemical parameters, the concentrations of Nitrates, Phosphates and Organic Matter were also above tolerable standards. The correlation coefficient between the heavy metal concentration and physicochemical parameters in the wet and dry seasons were determined, as well as the level of contributions of composite parameters to the heavy metal concentrations using Principal Component Analysis (PCA). A general multilinear model was developed using the transformed variables. Based on the findings, the study recommends:

1) Appropriate government agencies should as a matter urgency integrate the regular monitoring of waste disposal into the state developmental plan and framework in order to prevent excessive build-up of these metals in humans through the food chain, especially Hg, Cr and Mn.
2) Adequate measures should be put in place to create awareness on the ill effect arising from uncontrolled disposal of wastes to prevent harm to the environment and jeopardising our health.
3) There should improvement on the dearth of data and general information on environmental sanitation at all levels of government to facilitate planning, monitoring and evaluation.
4) Specific investigation and analysis will be needed to determine the exact sources and path ways of metal contamination in a particular refuse dumpsite since reasons for elevated metal concentration in dumpsite soils can vary, depending on the location, historical activities, waste management practices, and the types of materials discarded.

REFERENCES

Adamu, M. and Ahmad, Z. I. (2012). Multivariate statistical analysis and environmental modelling of heavy metals pollution by industries. *Pol. J. Environ. Stud*., 21(5), 1359 – 1367.

Adewuyi, G. O. and Opasina, M. F. A. (2010). Physicochemical and heavy metals assessment of leachates from Aperin Abandoned Dumpsite in Ibadan city, Nigeria. *E-Journal of Chemistry*, 7(4), 1278-1283 CODENECJAO https://unve-journals.net.

Adeyemi-Ale, O. A., Anifowoshe, A. T. and Abdulkareem, S. I. (2018). Ecotoxicological assessment of leachate from Amilegbe Dumpsite, Ilorin, Nigeria using *Clarias gariepinus* (Butchell 1822) and *Allium cepa*. *Agrosearch*., 18(2), 59-71. https://dx.doi.org/10.4314/agrosh.v1812.5.

Agbeshie, A. A., Adjei, R., Anokye, J. and Banunle, A. (2020). Municipal waste dumpsite: Impact on soil properties and heavy metal concentrations, Sunyani, Ghana. *Scientific African.* https://doi.org/10/1016/j.sciaf.

Akaeze, C. S. (2001). Solid waste analysis, characterization and management along Abak/IkotEkpene Roads of Uyo Metropolis. *A research project of Chemistry/Biochemistry Department, University of Uyo, Nigeria.* 7-15.

Akinbile, C. O., Nwankwoala, H. O. and Oyewole, N. O. (2017). Impact of municipal solid waste dumpsites on surrounding soil quality in Ibadan metropolis, Nigeria. *Journal of Environmental Science and Engineering*, 6(12), 533 – 546.

Akwa, V. L., Binbol, N. C., Samaila, K. I. and Markus, N. D. (2007). Geographical perspective on Nasarawa State. *A publication of Geography Department, Nasarawa State University, Keffi, Nigeria.* .8-15.

Amadi, O. N. and Nwankwoala, H. O. (2013). Evaluation of heavy metal on soils from Enyimba Dumpsite in Aba, Southeastern Nigeria, using contamination factor and geo-accumulation index. *Energy and Environmental Research*, 3(1).

Anake, W. U., Adie, G. U. and Osibanjo, O. (2009). Heavy metals pollution at municipal solid waste dumpsites in Kano and Kaduna States in Nigeria. *Bull. Chem. Soc. Ethiop.*, 23(1), 281-289.

Anthony, E., Isaa, E. and Derrick, A. (2021). Modeling of total dissolved solids in water supply systems using regression and supervised machine learning approaches. *Applied Water Science*, https://doi.org/10.1007/s.13201-020-01352-7.

Anzene, J. S. and Malu, P. S. (2014). Determination of levels of eight trace metals in ground water sources within and around Lafia metropolis. *International Journal of Innovative Science, Engineering and Technology. 1(5).* www.ijiset.com. 219-237

AOAC (2013). Official Methods of Analysis of the Association of Official Analytical Chemists. 17th Ed. *Association of Official Analytical Chemists*

Aremu, M. O., Atolaiye, B. O., and Labaran, L. (2010). Environmental implication of metal concentrations in soil, plant foods and pond in area around the derelict Udege Mines of Nasarawa State, Nigeria. *Bull. Chem. Soc. Ethiop.*, 24(3). 351-360.

Aremu, M. O., Atolaiye, B, O., Gav, B. L., Opaluwa, O. D., Sangari, D. U. and Madu, P. C. (2011). Metal concentrations in sediments and water from Rivers Doma, Farinruwa and Mada in Nasarawa State, Nigeria. *Journal of Environmental Chemistry and Ecotoxicology.* ISSN. 2142-226X. 242-249.

Arshi, I. and Khan T. I. (2018). Analysis of soil quality using physicochemical parameters with special emphasis on Fluoride tone selected sites of SawaiMadhopier Tehsil, Ajasthan. *International Journal of Environmental Sciences and Natural Resources*. 12(5)

Ayih, S. O. (2003). *Nasarawa State, Past and Present.* .2nd Ed. 1-10.

Benedicta, Y. F. M., Emmanuel A., Dzidzo, Y. T. and Frank, N. (2017). Heavy metals concentration and distribution in soils and vegetation at Korle Lagoon area in Accra, Ghana. *Cogent Environmental Science*, 6(2) 16-29. https://doi.org/10.1080/23311843.2017.1405887.

Beniah, O. I. and Christian, E. E. (2020). Pollution and health risks assessment of nitrate and phosphate concentrations in water bodies in South Eastern, Nigeria. *Environmental Advances.* www.Elsevier.com/locate/envadu.

Besufekad, M., Alemayehu, H. and Wuhib, Z. (2020). Assessment of effect of solid waste dumpsite on surrounding soil and River Water Quality in Tepi Town, South West Ethiopia. *Journal of Environ and Public Health,* 1-9 https://doi.org/10.1155/2020/5157046.

Carol, M. W. and Michael, C. E. (2011). Factor Analysis and Related Methods. Essential Statistical Methods for Medical Students. Science Direct.

Chessed, G., Sakiyo, D. C. and Yako, A. B. (2018). Concentration of heavy metals in soil around Dumpsites in Jimeta and Ngurore, Adamawa State, Nigeria. *Nigerian Annals of Pure and Applied Sciences*, Maiden edition, 105-112.

Daniel, C. S., Ifeoma, L. O. and Okechukwu, P. A. (2022). Multivariate and health risks analysis of heavy metals in natural water sources around Enugu Dumpsites, Southeastern Nigeria. *Applied Water Science,* 224(12) https://doi.org.10.1007/s13201-022001746-9.

Ebong, E. A., Akpan, M. M. and Mkpenie, V. N. (2008). Heavy metal contents of municipal and rural dumpsite soils and rate of accumulation by *Carica papaya* and *Triangulare* in Uyo, Nigeria. *E-Journal of Chemistry* ISSN: 0973-4945. https://www.e.journals-net.Elsevier.

Ebuga, E. A., Angbo, Y. B. and Obadiah, B. (2021). Impact of heat island on human comfort in Lafia urban area in Nasarawa State, Nigeria. *International Journal of Research on Innovation in Applied Sciences* (URIES) VI(XI). ISSN 2454 – 6194.

Ediene, V. F., and Umoetok, S. B. A. (2017). Concentration of heavy metals in soils at the municipal dumpsite in Calabar Metropolis. *Asian Journal of Environment & Ecology.* 3(2), 1-11. Doi:10.9734/AJEE/2017/34236.

Ekeu-Wei, I. T., Azuma, K. I. and Ogumuyiwa, F. B. B. (2018). *Nigerian Journal of Technology* (NIJOTECH) 37(1). www.nijotech.comhttp://doi.org/10.4314/njt.v.37:1.36.

Frances, S. S. and Eleanor, N. W. (2003). *Nutrition: Concepts and Controversies* .9th Edition. Thompson Wadsworth, pp. 266-295.

Franklyn. O. O., Kelechi, C. L., Paul, C. C., Andrew, W. V. and Christian, E. E. (2020). Pollution profile and ecological risk assessment of heavy metals from dumpsites in Ome, Rivers State, Nigeria. *Chemistry Africa*. https://doi.org/10.007/s 42250-20-00198-5.

Ganiyu, S. A., Badmus, B. S., Oladunjoye, M. A., Aizebeokhai, A. P., Ozebo, V. C., Idowu, O. A. and Olurin, O. T. (2016). Assessment of ground water contamination around active dumpsite in Ibadan, Southwestern Nigeria using integrated electrical resistivity and hydrochemical methods. *Environmental Health Sci.*, 75, 643. DOI 10.1007/sl2665-016-5463-2.

Gary, W. V. and Stephen, J. D. (2000) *Environmental chemistry, a global Perspective.* 386-435.

Henry, O. A., Adedotun, T. A., Abiodun, S. A., Oluwatoyosi, O. S. and Biola, K. B. (2017). Impact of Dumpsites on the quality of soil and groundwater in satellite towns of the Federal Capital Territory, Abuja. *J. Health Pollut.*, 7(14), 15-22. Doi:10.5696/2156-9614-7.14.15.

Ibe, F. C., Opara, F. I. and Ibe, B. O. (2020). Application of pollution risk evaluation models in groundwater systems in the vicinity of automobile scrap markets in Owerri Municipal and environs, Southeastern Nigeria. *Scientific African Elsevier* https://doi.org/10.1016/j.sciaf.2020e00450.

Isa, B. K., Syed, N. T. and Mohammed, A. H. D. (2018). A chemometric approach to the distribution and source identification of heavy metals in Tannery contaminated soil. *Int. J. of Theoretical and Appl. Sci.*, 10(1), 01-08.

Iwegbue C. M. A., Nwajei, G. E., Overah, C. L. and Ogala, J. E. (2010). Determination of trace metal concentrations in soil properties of municipal waste dumpsites in Nigeria. *Environ Geochem Health*, 32, 415-430. Doi. 10.1007/s10653-010-9285-y.

Iwegbue, C. M. A., Enuh, F. N., Isirimah, O. N. and Egun, A. C. (2007). Fractionation, characterization and speciation of heavy metals in composts and compost amended. *Soils, Afr. J. Biotechnol.*, 6(2), 067-078.
https://dx.doi.org/10.1098/rsta.2015.0202. 1-6.

Johnbosco, C. E. and Chukwuma, N. E. (2020). Chemometric analysis for pollution source identification and human risk assessment of water sources in Ojoto Province, Southeast Nigeria. *Applied Water Science*, https://doi.org/10.1007/s13201-020-01180-9.

Kabata-Pendias, A. (2011). *Trace elements of soils and plants* (4th Ed.). CRC Press, 528-534.

Lawan, I. B., Stephen, S. H., Goni, A. D. and Maimuna, W. (2012). Applicability of linear regression model for the estimation of mobility factor of heavy metals in contaminated soil native concentrations. *Journal of Advances in Analytical Chemistry*, 2(2), 1-5. Doi.10.5923/j.aac.20120202.01.

Lekan, O.A., Amos, A. O., and Abel, O. J. (2020). Evaluation of soil court amination status around municipal waste dumpsite using contamination indices, soil-quality guidelines, and multivariate statistical analysis. *SN Applied Sciences* 2,18-64 https://doi.org/10.1007/s42452-020-03678-4.

Mekonnen, B., Haddis, A. and Zeine, W. (2020). Assessment of the effect of solid waste dump site on surrounding soil and river water quality in Tepi Town, Southwest Ethiopia. *Journal of Environmental and Public Health*. Article ID 5157046 https://doi.org/10.1155/2020/5157046.

Mendham, J., Denney, R. C., Barnes, J. D. and Thomas, M. (2000). *Vogels Textbook of Quantitative Chemical Analysis.* 6th Edition, Prentice Hall, 117 – 169.

Mochamad, A. B., Amin, C. and Hamid, N. (2014). Prediction of heavy metal contamination from landfill: Lead and chromium. *Australian Journal of Basic and Applied Sciences*. 8(7), 207-214.

Nabil, N., Merc, E. B., Charbel L., Wissem, M., Issam, B. and Nasir, K. (2014). The influence of soil properties on the development of *Cephalciatannourinensis*, Chevin (*Hym. Pamphiliidae*) infesting the cedar forests in Lebanon. *Academic/Journals* 13 (47). 4381 http: //www. academicjournals.org/A/ B.

Ngoc, H. H., Anh, M. C., Kim, T. T. N. and Chi, H.L. (2022). A novel mathematical modeling for simulating the spread of heavy metals in solid waste landfills. *Environmental Engineering Research*, 27(3), 1-16. 210007. Doi:https/doi.org/10.4491/eer.2021.007.

Nnorom, I. C. and Osibanjo, O. (2021). Evaluation of heavy metal pollution and human health risk assessment in soils around informal electronic waste recycling workshops in Nigeria. *Journal of Environmental Monitoring and Assessment*. DOI: 10.1007/s10661-021-09267-5.

Obaliagbon, O. K. and Olowoyoba, G. B. (2006). Distribution of some heavy metals in leachates from a municipal waste dumpsite. *Paper presented at the International Conference on Engineering Research and Development, University of Benin, Benin city.*

Obasi, M. A., Akubugwo, E. I. U. and Glory, O. (2012). Assessment of physico-chemical properties and heavy metals bioavailability in dumpsites along Enugu-Port Harcourt Expressways, South-East, Nigeria. *Asian Journal of Applied Sciences*, 5, 342-356 DOI. 10.3923/ajabs.2012.342.356 URL: https://scialert.net/abstarct/?doi=ajabs.2012.346.356.

Ogundiran, O. O. and Afolabi, T. A. C. (2008). Assessment of the physicochemical parameters and heavy metals toxicity of leachates from municipal solid waste open dumpsite. *Int. J. Environ. Sci. Tech.*, 5(2), 243-250.

Oketola, A. A. and Akpotu, S. O. (2015). Assessment of solid waste and dumpsite leachate and topsoil. *J. of Chem. and Ecology*, 31(2), 134 - 146. https://doi.org/10.1080/02757540.2014.907280.

Olayinka, O. O., Akande, O. O., Bangbose, K. and Adetunji, M. T. (2007). Physicochemical characteristics and heavy metal levels in soil samples obtained from selected anthropogenic sites in Abeokuta, Nigeria. *J. Appl. Sci. Environ. Manage.* 1(5), 883-891.

Olukoya, A. B., Yisa, J. and Jacob J. O. (2019). Chemometric evaluation of heavy metals pollution patterns of soil in the vicinity of some dumpsites in Lokoja, Nigeria. *FUW Trends in Science & Technology Journal*, 4, 118-121. *www.ftstjournal.com*.

Opaluwa O. D., Aremu, M. O., Ogbo, L. O., Abiola, K. A., Odiba, I. E., Abubakar, M. M. and Nweze, N. O. (2012). Heavy metal concentrations in soils, plant leaves and crops grown around dumpsites in Lafia Metropolis, Nasarawa State, Nigeria. *Advances in Applied Science Research*, 3(2), 780-784. www.pelagiaresearchlibrary.com.

Orodu, V. E. and Morokowei, R. (2022). Determination of nitrates, sulphates and phosphates in Soil of Ogbiri and Adagbabiri farmlands in Bayelsa State; Nigeria. *Plant Nutr. and Soil Sci.. Int.*, 1(6). DOI: 10.239 77/PNSSI.2022.010101.

Rasool, B. M., Jianguo, L., Dongbei, Y. and Yongfeng, N. (2007). Biodegradation of organic matters from mixed unshredded municipal solid waste through air convection before landfilling. *Journal of the Air & Waste Mgt. Assoc.* Doi:10.1080/10473289.2007.10465296.

Raymond, A. W. and Felix, E. O. (2011). Heavy metals in contaminated soils. A review of sources, chemistry, risks and best available strategies for remediation. *International Scholarly Research Network.* Article ID 402 647. Doi:10.5402/2011/402647. 1-20

Roseline, O. O., Adewale, F. L., Golan, B. M. K., Joseph, B. A. and Benedicta, B. A. (2020). Predictive modeling of COVID-19 confirmed cases in Nigeria. *Infect Dis Model.* Doi.10.1016/j.idm. 543-548.

Ruben, D. L; Pedro, V. and Guillermo, M. (2015). The screen test and the number of factors: A dynamic graphics approach. *Spanish Journal of Psychology*. 18, e11, 1-10 doi:10.1017/sjp.

Ruth, O. E. U., Wisdom, C. U. and Moses, O. E. (2021). Qualitative analysis of physical and chemical attribute of soil around power-line dumpsite at Boji-BojiOwa, Delta State, Nigeria. *World News of Natural Sciences*, 35, 118-334.

Saanu, E. K. and Josephine, B. E. (2017). Toxicity Assessment Using *Clarias gariepinus* and Microbial Characterization of Leachate from Akomo municipal solid waste landfill, Igbemo – Ekiti, Ekiti State, Nigeria. *Journal of Environmental Pollution and Human Health*, 5(3), 83-88. DOI: 10.12691/jephh-5-3-1.

Sabyasachi, R., Ajay, K., Sarkar, P. K., Manish, K. and Mishra, P. M. (2013). Application of chemometric methods for assessment of heavy metals pollution and source apportionment in Riparian zone soil of Ulhas River estuary, India. *Int. J. of Environmental Sci.*, 3(5), 1-12, Doi:10.6088/ijes.2013030500019.

Saheed, I. O., Azeez, S. O., Jimoh, A. A., Obaro, V. A. and Adepoju, S. A. (2020). Assessment of some heavy metals concentrations in soil and groundwater around refuse dumpsite in Ibadan Metropolis, Nigeria. *Nigerian Journal of Technology (NIJOTECH)*, 1(39), 301-305. http://dx.doi.org/10.4314/njit.v39i.33

Saida, M. C., Arezki, D., Djaber, T. and Rym, S. (2019). A study of the impact of municipal solid waste (MSW) on some soil physiochemical properties. The case of the landfill of Ain-El-Hammam Municipality, Algeria. *Applied and Environmental Soil Science* ID 3560456 https://doi.org/10.1155/2019/3560456. 185-195

Sylvester, C. I., Sunday, E. B., and Elijah, I. O. (2017). Assessment of pollution load indices of heavy metals in cassava mill effluents of contaminated soil: A case study of small-scale processors in a rural community in the Niger Delta, Nigeria. *Bioscience Methods*, 8(1), 1-17.

Thelma, A., Boakye S., Lawrence, S. B., Matt, D. and Godfred, D. (2020). Distribution of Heavy Metals and Soils from abandoned dumpsites in Kumasi, Ghana. *Scientific African.* https@//doi.org/10.1016/j.sciaf.

Torres-Bejarano, F., Couder-Castanada, C., Ramirez-leon, H., Hernandez – Gomez, J. J., Rodriquez-Cueves, C., Herrara-Diaz, I. E. and Barrios-Pina, H. (2019). Numerical modelling of heavy metal dynamics in a river-lagoon system. *Mathematical Problems in Engineering.* Article ID 8485031, 1- 24. https://doi.org/10.1155/2019/848503/

Tukura, B. M., Anhwamge, B., Mohammed, Y. and Usman, N. L. (2012). Translocation of trace metals in vegetable crops grown in irrigated soil along Mada River, Nasarawa State, Nigeria. ResearchGate.

Vincent, K. N., Ebenezer, K. H. and Smile, K. A. (2012). Assessment of the impact of solid waste dumpsites on some surface water systems in the Accra Metropolitan Area, Ghana. *Scientific Journal of Resource and Protection*, 4, 605-650.

Vodyanitskii, Y. N. (2016). Standards for the contents of heavy metals in soils of some states. *Annals of Agrarian Science*, 14, 257-263 http://www/journals.elsevier.com/http://dx.doi.org/10.1016/j.ansci.

Zauro, S. A., Dabai, M. U., Tsafe A. I., Umar, K. J., and Lawal, A. M. (2013). Extent of some heavy metal contaminator in soil of farmlands around Sokoto metropolis. *Euro. Scien. J.*, 9(3), 30-36.