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Determination of Heavy Metal Concentrations at Ewu-Elepe, Ikorodu Dumpsite, Lagos, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Heavy metal contamination of soil at dumpsites poses risks and hazards to humans and the ecosystems through inhalation of dust particles or dermal contact with the contaminated soil. Dumpsites are usually located at the outskirts of residential areas, but due to population increase in the urban centers as result of rural-urban movement which has become living habitats without considering the health implications. Thus, Ewu-Elepe dumpsite, located on the outskirts of Ikorodu, Lagos may pose a serious threat to residents of this area due to the improper disposal and ineffective management of waste at the dumpsite also, due to the metalic health issue recorded in this area. Therefore, this study was designed to determine the Heavy Metal Concentrations (HMC) and identify the type of Key Environmental Indicators (KEIs) responsible for the heavy metal contamination at the dumpsite. The Principal Component Analysis (PCA), Nemerow Integrated

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Pollution Index (NIPI), and Pollution Index (PI) procedures were adopted. The Akaike Information Criteria (AIC) was employed to determine the best KEI responsible for the presence of a particular heavy metal on the dumpsite. The Heavy Metals (HMs) found on the dumpsite were Zinc, Copper, Lead, Cadmium, Calcium, Manganese, and Iron. The identified KEIs on the dumpsite were: potential Hydrogen (pH), Electrical Conductivity (EC), Total Organic Carbon (TOC), Total Nitrogen (TN), Phosphorous (P), and Carbon Exchange Capacity (CEC). The AIC at 5% showed that the most significant KEI responsible for Zn was EC with the least value (16.21), pH for Pb (26.70), P for Ca (20.71), TOC for Cu (24.61) and Mn (81.09), TN for Cd (44.97), and CEC for Fe (41.04). The PCA and NIPI estimates for the heavy metals across the 20 sample points were (1760.57, 3.00); (1825.85, 2.30); (1330.80, 2.60); (1644.68, 2.40); (1602.57, 9.70); (1469.93, 2.40); (1379.85, 3.20); (1872.82, 2.40); (1859.30, 8.40); (1397.56, 2.30); (1995.32**,** 4.70); (1518.62, 3.10); (1565.33, 1.80); (1332.29, 5.10); (1748.59, 2.50); (1664.70, 3.90); (1792.24, 4.10); (1801.79, 2.30); (1801.18, 2.30); (1743.27, 2.00), respectively, implying that the dumpsite was highly concentrated in HMs. Copper, lead, cadmium, calcium, manganese, and iron highly polluted Ewu-Elepe dumpsite with potential hydrogen, electrical conductivity, total organic carbon, total nitrogen, phosphorous, and carbon exchange capacity as the key environmental indicators for the heavy metals.

Keywords: Heavy metal contamination; pollution levels; key environmental dumpsite indicators; nemerow integrated pollution index; akaike information criteria.

1. INTRODUCTION

Increase in world population with its associated high industrial activities has resulted in the production of large volumes of domestic, municipal and industrial wastes, Large et. al. [1]. Dumpsites are usually located at the outskirts of residential areas, but due to population increase in the urban centers as result of rural-urban movement, these reserved areas have become living habitats without considering their health.

The accumulation of heavy metals and metalloids through emission from the rapidly expanding industrial areas and other human activities on the earth's surface such as mining failings, disposal of high metal wastes Akanbi O. B. [2] leaded gasoline [3] Akanbi O. B. [4] and paints, land application of fertilizers, animal manures, sewage sludge, pesticide, waste water irrigation, coal combustion residues Akanbi and Oladoja [5] spillage of petrochemicals, and atmospheric deposition may have resulted into soil contamination Raymond et al. [6]. Heavy metals released into the environment by human activities are mainly submerged into the soil, Kirpichtchikora et. al. [7] and their total concentration in soil persists for a long time after their introduction Adriano [8]. The contaminated soil harms the food chain [9] causing drinking of contaminated groundwater, reduction in food quality, and reduction in land availability for agricultural production causing food insecurity and land tenure problems McLaughlin et al. [10] and Ling et al. [11]. The indiscriminate and improper disposal and management of waste have posed immense threats to the environment and development of major towns worldwide, especially in Africa, Lebreton et al. [12]. Nurudeen et al. [13] investigated the concentration of heavy metals at the Oke-Afa refuse dump and found that the refuse dump was highly polluted with cadmium and copper which have adverse health implications for the residents around the refuse dump. Agbeshie et al. [14] conducted a study on soils around Sunyani municipal waste dumpsite in rural and urban areas in Ghana to determine the heavy metal concentration permissible level for food production, especially vegetables. Olorunfemi et al. [15] investigated the heavy metal concentration level of the soil around the Ewu-Elepe dumpsite to determine the effect on the surrounding environment.

The environmental issues require the analysis of several variables simultaneously; hence, Principal Component Analysis can be applied to maintaining the data structure and reducing the dimensions of multivariate data set into fewer principal components (PCs) [16]. Kejian Chu et al. [16] developed a concept for identifying the key environmental indicators responsible for the determination of environmental variables and their nonlinear interrelationships. Shiguo Xu et al. [17] applied fuzzy comprehensive evaluation and principal component analysis methods to assess the water quality to extract the principal pollutants of the Nansi Lake Basin and to evaluate the importance of various water quality per meter. Exposure to heavy metals has been linked to serious consequences for human health, such as heart and skeletal diseases, infertility, and various neurological disorders Briki, et al. [18]. The excessive accumulation of heavy metals in the human body can cause various effects on different physiological functions, which leads to three pathogeneses: carcinogenesis, teratogenesis, and mutagenesis Dasharathy, et al. [19]. Miranzadeh, et al. (2020) observed that the heavy metals in soils can affect air quality because they can create particulate matter and dust. Most of the research conducted focuses on the contamination of surrounding soils of dumpsites by heavy metals without its estimation Agbeshie et. al, (2020); Olorunfemi et. al. [15] Lagerkvist et al. [1]. Therefore, the purpose of this study was to determine the degree of pollution level in the Ewu-lepe dumpsite by heavy metals but not in its surroundings.

2. REVIEW OF LITERATURE

Pepper et al. [20] observed that soil is an essential valuable commodity in the world that cannot be underestimated and is essential for the production and quality of food, provision of raw materials and services as well climate regulation.

Khan, et al. [21] opined that despite the enormous scientific progress made to date, protection and monitoring of soil conditions at national and global levels still face various challenges, threatening the effective on-the-ground policy design and decision-making.

Scull and Okin, [22] opined the understanding and evaluation of environmental changes due to general public orientation and awareness has shown rapid growth in recent periods.

Kirpichtchikora, et al. [7] stated that soil is the bedrock for the activities on the earth's surface and plays important role in the life of plants and animals, the rocks and amazing environment of the intricate natural system that is beyond what any machine that man created cannot be underestimated.

Al-Swadi, et al. [23] opined that human activities in urban centers contributed to the accumulation of heavy metals and other environmental pollutants.

Wang, et al. [24] stated that the exposure to heavy metals might pose threats to human health.

Binner, et al. [25] discovered greater risks to human health in the urban center than the suburbs due to population concentration in cities.

Piyawat et al. [26] adapted principal component analysis with varimax rotation in determining the key elements that influence sediment yield and applied multiple regression analysis to establish the relationships between yield and characteristics of the basin in terms of geomorphology and climate.

Ghaemi et al. [27] adopted Principal Component Analysis in selecting more effective indicators that conformed with the minimum data set.

Everitt et al. [28] used Principal Component Analysis to determine the relationship and variance in the data set and at the same time reduce the number of variables to smaller variables.

Wei Zhiyuan et al. [29] applied the Principal Components Analysis and Geocumulation Index in determining the pollution status of heavy metals in the mining field of copper and compared the result with values from the Hakanson potential ecological risk index.

Tao et al. [30] applied Principal Components Analysis on multi confidence ellipse study, to determine weak information between data sets.

Jollie et al. [31] applied Principal Component Analysis to minimize information loss and increase interpretability by reducing the dimensionality of large data sets.

Jin Ling et al. [32] adopted a multivariate statistical method in determining the average regional concentration of some heavy metals, specifying their natural or anthropogenic sources and determining other sources causing contamination in topsoil.

3. METHODS AND STATISTICAL FRAMEWORK

3.1 Source of Data

Data used for this study was obtained from the samples of soil collected from Ewu-Elepe dumpsite, Ikorodu, Lagos, Nigeria.

3.2 Sample Collection and Design

The dumpsite was partitioned into two and an adaptive sampling technique was used to collect a total of sixty soil samples, 30 from each partition at three levels: the surface, 1.5m, and 3m depths respectively using a hand auger and stored in properly labeled sample tubes. The sixty sample estimates were averaged over the three levels to have twenty sample point estimates for the two locations. The samples were air-dried at room temperature (21^{o}c - 27^{o}c) for seven days and later over-dried at 100^{o}c for one hour to obtain a constant weight. The samples were then dissipated using mortar and pestle and then sieved. The samples sieved were then put into a prescription sachet well labeled to determine the quantity of the heavy metals. The process of determining the heavy metals was achieved by measuring 1g of the filtered samples into a conical flask and digesting the sample aqua regia (a combination of HCL and HNO_3 in a ratio of 3:1). Two drops of distilled water with necessary reagents were added to the samples put in the conical flask under laboratory condition to obtain the required solution for final results. The final solution was processed to determine the heavy metals presence in the samples. The Key Environmental Indicators were identified by some laboratory tests on the dumpsite's soil.

The types and estimates of the Key Environmental Indicators (KEIs): potential Hydrogen (pH), Electrical Conductivity (EC), Total Organic Carbon (TOC), Total Nitrogen (TN), Phosphorous (P), Carbon Exchange Capacity (CEC) and Heavy Metals (HMs): Zinc (Zn), Copper (Cu), lead (Pb), Cadmium (Cd), Calcium (Ca), Manganese (Mn) and Iron (Fe) on the dumpsite were determined using the laboratory tests and Atomic Absorption Spectrophotometer (AAS).

3.3 Determination of Soil Contamination

The Pollution Index (PI) and the Nemerow Integrated Pollution Index (NIPI) are measures used in the assessment of the amount of heavy metal in the soil.

Generally,

$$P_{ij} = \frac{C_{ij}}{S_j}, S_j > 0 \quad \forall j \tag{1}$$

$$NIPI = \sqrt{\frac{(P_{max}^2 + P_{ave}^2)}{2}} \tag{2}$$

where

C_{ij} = concentration of heavy metal in the soil at location i for heavy metal j,

i = the environmental quality standard value of heavy metal *i*

When pi < 1, it implies no metal pollution; otherwise,

if $P_{ij} > 1$, it implies metal pollution.

The Nemerow Integrated Pollution Index (NIPI) consider not only the mean value (P_{ave}) of all metals involved but also the maximum value (P_{max}) of all heavy metals involved Yang et al., (2011).

4. RESULTS AND DISCUSSION

4.1 Assessment of Heavy Metal Concentrations Ewu-Elepe Dumpsite by PCA, NIPI, and PI

The contents of heavy metals (*Zn, Cu, Pb, Cd, Ca, Mn, and Fe*) and assessment standard were shown in Table 1.

4.2 Determination of Concentration Levels of Ewu-Elepe Dumpsite Soil by PRINCIPAL Component Analysis (PCA)

Principal Component Analysis is a statistical tool used to reduce the original variables into smaller new uncorrelated variables called the principal components. These new uncorrelated variables are linear combinations of the original variables with the same number of new and old variables Johnson et al [33]. Principal Component Analysis (PCA), a multivariate statistical method, was proposed by Hotelling in 1933 and was cited by Haung et.al (2007). Based on the principal component scores, PCA can examine the multivariate relationships and explain the variance in the data while reducing the number of variables to several groups of individuals Everitt et.al [34]. Since Principal Component Analysis allows a considerable reduction in the number of variables and the detection of structure in the relationships of different variables; it was applied in different areas by researchers Rencher et, al 2002). To assess the soil heavy metal concentration levels by PCA, the principal components of the data set were identified. The principal components, which contain most of the information of assessed indexes, presented the contamination levels of heavy metals in soil correctly. During the processes of PCA, the variances of a linear combination of the variables datasets were maximized. The values of principal components were calculated by the contents of heavy metals in the sample soils collected from the dumpsite and the contamination levels of heavy metals in the soil were assessed by the weighted sum of different principal component values. Principal Component Analysis of normalized variables was performed to extract significant principal components and to reduce the effect of variables with minimal significance. Brumelis et. al. [35] Singh et al., [36] Abdul-Wahab et al. [37].

Table 1. Heavy metals concentrations statusof the dumpsite compared to WHO standard

Location	Zn	Cu	Pb	Cd	Ca	Mg	Fe
B_1	118.8164	47.4711	30.2347	3.1087	3928.3430	114.1138	806.2452
B_2	145.0692	38.4388	8.4114	2.3646	4164.2830	102.3076	741.5511
B_3	83.6611	20.5187	21.9922	2.7900	2918.3420	108.1551	710.0920
B_4	153.1641	51.7907	40.8047	1.3691	3624.1290	106.3960	779.5941
B_5	136.9348	63.6403	33.1586	10.7278	3544.6020	107.7907	756.1394
B_6	124.1598	46.9581	25.1240	2.4729	3335.5590	110.6935	801.5553
B_7	116.3530	32.4583	63.2691	3.4183	2979.7620	107.9496	769.6873
B_8	149.2570	80.9240	62.8542	0.7772	4220.3110	109.5657	822.2035
B_9	172.1804	413.3322	53.0474	1.0088	4054.2200	110.0662	786.0355
B_{10}	106.3813	28.1791	7.4037	2.3966	3001.2300	112.3331	826.0109
B_{11}	167.1333	229.6797	49.7142	0.3073	4453.9630	115.4284	793.1297
B_{12}	124.2802	87.2630	27.3261	3.1845	3292.5000	110.538	808.9314
B_{13}	109.6553	42.9557	21.5009	1.7752	3448.7770	110.8665	784.5473
B_{14}	149.4122	134.6934	51.9642	5.4376	2979.8010	111.4944	532.1158
B_{15}	157.2165	41.4881	41.4244	2.0223	3894.4260	109.0698	774.9694
B_{16}	136.1891	57.0831	61.7760	4.1620	3674.3770	110.4616	795.3494
B_{17}	111.1982	45.9883	31.7000	4.3623	4014.6900	109.5253	804.6700
B_{18}	135.2297	68.1279	52.9851	2.1864	4047.6230	108.9411	754.7232
B_{19}	148.6097	72.0858	27.2405	0.5787	4005.3300	114.7938	808.5040
B_{20}	108.9542	25.7974	28.5252	2.0313	3919.0120	105.6132	766.3681
WHO Min	30.8000	28.5500	24.0000	0.0200	400.0000	30.0000	500.0000
WHO Max	219.2300	115.2000	397.0000	0.8000	4500.0000	150.0000	2000.0000
WHO Ave.	50.0000	36.0000	85.0000	0.8000	2500.0000	100.0000	1000.0000

WHO: World Health Organization gave the standard desirable maximum levels of elements for polluted soils [WHO (1996)], Ogundele et al. (2015).

Let $X = (C_{ijk})$ content of heavy metals in the soil sample collected from Ewu-Elepe dumpsite, where; C = concentration of heavy metals in the sample soils; i = different heavy metals (*Zn, Cu, Pb, Cd, Ca, Mg, and Fe*); j = sample numbers (location points ($B_1, B_2, \ldots, B_{20}$)) k = KEI of the sample point. The result of principal component analysis is presented in Table 2. For the fact that the first three principal components account for 74.2% of the total variance, they can represent the soil heavy metals concentration levels in the Ewu-Elepe dumpsite. The values of these three principal components can be presented by the contents of heavy metals in soil and the Eigenvectors of principal components.

$$Z_1 = 0.5285Zn + 0.4836Cu + 0.3495Pb - 0.3038Cd + 0.4526Ca + 0.2245Mg + 0.1309Fe \quad (3)$$

$$Z_2 = -0.2308Zn - 0.2257Cu - 0.4008Pb - 0.4559Cd + 0.2633Ca + 0.1172Mg + 0.6665Fe \quad (4)$$

$$Z_3 = 0.1988Zn - 0.1587Cu - 0.0328Pb + 0.0508Cd + 0.4228Ca - 0.8675Mg + 0.0156Fe \quad (5)$$

where Z_1, Z_2, Z_3, are respectively principal components values; e_1, e_2, e_3 are the Eigen vectors

To obtain the overall contamination level of heavy metals, the values of Z_1, Z_2, Z_3 were weighed and summed by each of the respective eigenvalues, hence the Principal Component Analysis Model was given by :

$$PCA_{B_i} = \frac{Z_{1B_i}(\lambda_1)}{(\lambda_1 + \lambda_2 + \lambda_3)} + \frac{Z_{2B_i}(\lambda_2)}{(\lambda_1 + \lambda_2 + \lambda_3)} + \frac{Z_{3B_i}(\lambda_3)}{(\lambda_1 + \lambda_2 + \lambda_3)} \quad (6)$$

Where $\lambda_1, \lambda_2 ... \lambda_3$ are the eigenvalues, $B_1, B_2, \ldots, B_n$, are sample points and Z_1, Z_2, Z_3, are respectively principal components values.

The results obtained were used to determine the heavy metals concentrations at the dumpsite for the first sample point (i=1), and are presented below;

Z_{1B1} = 0.5285Zn + 0.4836Cu + 0.3495Pb − 0.3038Cd + 0.4526Ca + 0.2245Mg + 0.1309Fe
= (118.8164) + 0.4836(47.4711) + 0.3495(30.2347) - 0.3038(3.1087) + 0.4526(3928.3430) + 0.2245(114.1138) + 0.1309(826.2452)
= 2004.4980

Z_{2B1} = −0.2308Zn − 0.2257Cu − 0.4008Pb − 0.4559Cd + 0.2633Ca + 0.1172Mg+ 0.6665Fe
−0.2308(118.8164) − 0.2257(47.4711) − 0.4008(30.2347) − 0.4559(3.1087) + 0.2633(3928.343)+ 0.1172(114.1138) + 0.6665(806.2452)
= 1533.3970

Z_{3B1} = 0.1988Zn − 0.1587Cu − 0.0328Pb + 0.0508Cd + 0.4228Ca − 0.8675Mg + 0.0156Fe
0.1988(118.8164) − 0.1587(47.4711) − 0.0328(30.2347) + 0.0508(3.1087) + 0.4228(3928.343) − 0.8675(114.1138) + 0.0156(806.2452)
= 1589.3970

Recall:

$$PCA_{B_i} = \frac{Z_{1B_i}(\lambda_1)}{(\lambda_1 + \lambda_2 + \lambda_3)} + \frac{Z_{2B_i}(\lambda_2)}{(\lambda_1 + \lambda_2 + \lambda_3)} + \frac{Z_{3B_i}(\lambda_3)}{(\lambda_1 + \lambda_2 + \lambda_3)}$$

PCA_{B1} = 2004.498(1.725)/(3.806) + 1533.397(1.0842)/(3.806) + 1589.397(1.0214)/(3.806)
= 902.6678 + 434.0074 + 423.892
= 1760.5670

Similarly, the result of the comprehensive concentration levels of heavy metals for the whole sample points using the Principal Component Analysis procedures are presented in Table 3.

Table 3 shows the comparison of the results with the NIPI criteria, sample points B_5 and B_9 were highly polluted while other sample points are moderately polluted. On the other hand, Pollution Index (PI) showed that lead and iron are less than I, which indicated that the dumpsite was not polluted with lead and iron while other heavy metals (zinc, copper, cadmium, calcium, and manganese) are above 1 which show that the dumpsite is polluted by the heavy metals.

4.3 Key Environment Indicators

The analysis of the samples of soil collected from the Ewu-Elepe dumpsite revealed the listed Key Environmental Indicators (KEI) that added to the concentration level of heavy metals of the dumpsite: Potential of Hydrogen (pH); Electrical Conduction (s/cm) (EC); Total Organic Carbon (%) (TOC);. Total Nitrogen (%) (TN); Phosphorus (mg/kg) (P); Carbon Exchange Capacity (Cmol/kg) (CEC).

Table 2. The Eigen values and Eigen vectors obtained from Ewe-Elepe dumpsite data

Component	Eigen values (λ)	Proportion	Cumulative	Elements	Eigen vectors (*e*)		
					Comp 1	**Comp 2**	**Comp 3**
1	1.7250	0.4251	0.4251	Zn	0.5285	-0.2308	0.1988
2	1.0842	0.1679	0.5930	Cu	0.4836	-0.2257	-0.1587
3	1.0214	0.1490	0.7420	Pb	0.3495	-0.4008	-0.0328
4	0.8426	0.1014	0.8434	Cd	-0.3038	-0.4559	0.0508
5	0.7314	0.0764	0.9198	Ca	0.4526	0.2633	0.4228
6	0.6223	0.0553	0.9751	Mg	0.2245	0.1172	-0.8675
7	0.4163	0.0248	1.0000	Fe	0.1309	0.6665	0.0156

Table 3. The Results of PCA, NIPI and PI

Location	PCA	NIPI	PI						
			Zn	Cu	Pb	Cd	Ca	Mg	Fe
B_1	1760.5700	3.0000	2.3800	1.3200	0.3600	3.8900	1.5700	1.1400	0.8100
B_2	1825.8500	2.3000	2.9000	1.0700	0.1000	2.9600	1.6700	1.0200	0.7400
B_3	1330.8000	2.6000	1.6700	0.5700	0.2600	3.4900	1.1700	1.0800	0.7100
B_4	1644.6800	2.4000	3.0600	1.4400	0.4800	1.7100	1.4500	1.0600	0.7800
B_5	1602.5700	9.7000	2.7400	1.7700	0.3900	13.4100	1.4200	1.0800	0.7600
B_6	1469.9300	2.4000	2.4800	1.3000	0.3000	3.0900	1.3300	1.1100	0.8000
B_7	1379.8500	3.2000	2.3300	0.9000	0.7400	4.2700	1.1900	1.0800	0.7700
B_8	1872.8200	2.4000	2.9900	2.2500	0.7400	0.9700	1.6900	1.1000	0.8200
B_9	1859.3000	8.4000	3.4400	11.4800	0.6200	1.2600	1.6200	1.1000	0.7900
B_{10}	1397.5600	2.3000	2.1300	0.7800	0.0900	3.0000	1.2000	1.1200	0.8300
B_{11}	1995.3200	4.7000	3.3400	6.3800	0.5800	0.3800	1.7800	1.1500	0.7900
B_{12}	1518.6200	3.1000	2.4900	2.4200	0.3200	3.9800	1.3200	1.1100	0.8100
B_{13}	1565.3300	1.8000	2.1900	1.1900	0.2500	2.2200	1.3800	1.1100	0.7800
B_{14}	1332.2900	5.1000	2.9900	3.7400	0.6100	6.8000	1.1900	1.1100	0.5300
B_{15}	1748.5900	2.5000	3.1400	1.1500	0.4900	2.5300	1.5600	1.0900	0.7700
B_{16}	1664.7000	3.9000	2.7200	1.5900	0.7300	5.2000	1.4700	1.1000	0.8000
B_{17}	1792.2400	4.1000	2.2200	1.2800	0.3700	5.4500	1.6100	1.1000	0.8000
B_{18}	1801.7900	2.3000	2.7000	1.8900	0.6200	2.7300	1.6200	1.0900	0.7500
B_{19}	1801.1800	2.3000	2.9700	2.0000	0.3200	0.7200	1.6000	1.1500	0.8100
B_{20}	1743.2700	2.0000	2.1800	0.7200	0.3400	2.5400	1.5700	1.0600	0.7700

Table 4. Descriptive Statistics of Key Environmental Indicators (KEI)

KEI	Minimum	Maximum	Mean	Std. Deviation
Ph	3.29	5.76	4.49	0.56
Ec	140.98	497.40	320.81	53.21
TOC	0.46	1.44	0.89	0.22
TN	0.09	0.15	0.12	0.02
P	51.42	80.42	65.92	8.73

Table 5. Karl Pearson Correlation Coefficient ® for Key Environmental Indicators

	pH	Ec	TOC	TN	P	CEC
pH	1	-0.370 (0.108)	0.028 (0.908)	0.272 (0.246)	0.100 (0.676)	0.306 (0.189)
Ec		1	0.009 (0.971)	-0.360 (0.119)	-0.036 (0.881)	-0.210 (0.374)
TOC			1	-0.238 (0.313)	0.421 (0.065)	-0.419 (0.066)
TN				1	0.116 (0.627)	0.109 (0.647)
P					1	0.006 (0.979)
CEC						1

The descriptive statistics of the key environmental indicators obtained from the soil samples collected at Ewu-Elepe dumpsite in Table 4 revealed that Total Nitrogen has minimum value among KEIs, Electrical Conductivity has highest maximum value, Total Nitrogen displays the minimum value for mean and standard deviation among other key environmental indicators. The comparison with the results of Oviasogie et.al. [38] showed that the dumpsite is moderately polluted by the key environmental indicators [39,40].

Table 5 presents the Karl Pearson correlation coefficient (r) and their corresponding p-values for the key environmental indicators. It showed that there is no significant correlation among all the key environmental indicators; hence there is no multicollinearity among the key environmental indicators, which are the independent variables in the models [41].

The relationship between the key environmental indicators and the heavy metals was determined using linear models (Gaussian and Gamma distributions) with their logarithms to form eight models used for the analysis. To establish the key environmental indicator, responsible for the presence of a particular heavy metal in the dumpsite, Akaike Information Criteria (AIC) were used. The six key environmental indicators were used as independent variables and NIPI as the dependent variable using the four models for the analysis. The model selection using Akaike Information Criteria was used to determine the best model and key environmental indicators with the most significant independent variable responsible for the concentration of a given heavy metal in the dumpsite. The eight models considered eventually resulted in the best fit with the selection of the most significant independent variable. The AIC result showed the most significant independent variable KEI responsible for Zn was EC with the least value (16.21), pH for Pb (26.70), P for Ca (20.71), TOC for Cu (24.61) and Mn (81.09), TN for Cd (44.97), and CEC for Fe (41.04). PCA, NIPI, and PI showed that the dumpsite is polluted with heavy metals [42,43].

The comprehensive results of PCA, NIPI, and PI in Table 2 showed that the dumpsite was highly polluted with heavy metals and had the highest concentration at points B_{11}, $B_{8,}$ and B_9 with values 1995.32, 1872.82, and 1859.30 respectively. Also, NIPI showed that sample points B_5 and B_9 with values of 9.7 and 8.4 of the dumpsite are highly polluted and sample point B_{14} with a value of 5.1 is highly polluted with heavy metals. However, the PI values of lead and iron were below the standard revealing that the duo posed no environmental threats Ewu-Elepe dumpsite. On the other hand, zinc, copper, cadmium, calcium, and manganese were highly polluted in the dumpsite. Thus, based on the findings of this study, it has been established that Ewu-Elepe dumpsite is highly polluted with heavy metals concentrations [44].

5. CONCLUSION

Based on the findings obtained from the analysis of the soil samples collected from Ewu-Elepe dumpsite using Principal Component Analysis, Nemerow Integrated Pollution Index, Pollution Index and Akaike Information Criteria revealed that copper, lead, cadmium, calcium, manganese, and iron highly polluted Ewu-Elepe dumpsite with potential hydrogen, electrical conductivity, total organic carbon, total nitrogen, phosphorous and carbon exchange capacity as the key environmental indicators for the heavy metals.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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