Heavy Metal Contamination of a Dumpsite Environment as Assessed with Pollution Indices

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***Abstract*—**Indiscriminate refuse dumping in and around Ado-Ekiti combined with improper management of few available dumpsites, such as Ilokun dumpsite, posed the threat of heavy metals pollution in the surrounding soils and underground water that needs assessment using pollution indices. Surface soils (0-15 cm) were taken from the centre of Ilokun dumpsite (0 m) and environs at different directions and distances during the dry and wet seasons, as well as a background sample at 1000 m away, adjacent to the dumpsite at Ilokun, Ado-Ekiti, Nigeria. The concentration of heavy metals used to calculate the pollution indices for the soils were determined using Atomic Adsorption Spectrophotometer. The soils recorded high concentrations of all the heavy metals above the background concentrations irrespective of the season with highest concentrations at the 0 m except Ni and Fe at 50 m during the dry and wet season, respectively. The heavy metals concentration were in the order of Ni > Mn > Pb > Cr > Cu > Cd > Fe during the dry season, and Fe > Cr > Cu > Pb > Ni > Cd > Mn during the wet season. Using the Contamination Factor (CF), the soils were classified to be moderately contaminated with Cd and Fe to very high contamination with other metals during the dry season and low Cd contamination (0.87), moderate contamination with Fe, Pb, Mn and Ni and very high contamination with Cr and Cu during the wet season. At both seasons, the Pollution Load Index (PLI) indicates the soils to be generally polluted with heavy metals and the Geoaccumulation Index (I_{geo}) calculated shown the soils to be in unpolluted to moderately polluted levels. Enrichment Factor (EF) implied the soils to be deficiently enriched with all the heavy metals except Cr (7.90) and Cu (6.42) that were at significantly enrichment levels during the wet season. Modified Degree of Contamination (mC_d) recorded, indicated the soils to be of very high to extremely high degree of contamination during the dry season and moderate degree of contamination during the wet season except 0 m with high degree of contamination. The concentration of heavy metals in the soils combined with some of the pollution indices indicated the soils in and around the Ilokun Dumpsite are being polluted with heavy metals from anthropogenic sources constituted by the indiscriminate refuse dumping.

***Keywords*—**Contamination factor, enrichment factor, geoaccumulation index, modified degree of contamination, pollution load index.

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I. INTRODUCTION

IN Ado-Ekiti and most developing towns in Nigeria where increase in population and industrial activities were being experienced mostly due urbanization resulting from the geographical positioning of such towns in the locality, has led to indiscriminate dumping of refuse of various sources in and around any available large expanse of land either under fallow or abandoned by the land owners. These expanses of lands were gradually being turned into dumpsites for domestic and industrial purposes [1], such as Ilokun Dumpsite in Ado-Ekiti, Nigeria where the waste dumped ranges from market, automobile mechanic workshop, painting and panel beating workshop, household, agricultural and industrial wastes. Toxic heavy metals, hydrocarbons and other compounds from these wastes puts the dumpsites' environments in severe threat as some of these metals persist in the soil due to their non-degradable nature.

High heavy metal concentrations in the soils do not necessarily reflect anthropogenic source [2], but may rather originate diagenetically [3] or grain sized effects [4]. A crucial step in assessing soil pollution with toxic elements is to establish the expected heavy metals background or baseline concentration levels [5], [6], from which the anthropogenic inputs can then be quantified using various pollution indices or approaches. The environmental pollution of soils in and around the Ilokun Dumpsite with heavy metals has not been previously investigated. Therefore, the aim of this study is to assess the distribution, sources and degree of heavy metals pollution in surface soils using the CF, PLI, modified degree of contamination, EF and geoaccumulation index.

II. MATERIALS AND METHODS

A. Description of Study Area

The study dumpsite environment is located at Ilokun Community in Ado Local Government Area of Ekiti State, Nigeria (Longitude 5^{o} 15' E and Latitude 7^{o} 41' N). It is in the lowland tropical rainforest and characterized by distinct wet and dry seasons, wet season starts from April to October while dry season starts from November to March with an accompanied dry cold harmattan period during the months of December and January. The annual mean rainfall is about 1800 mm and the annual mean temperature is about 28^{o}C with over 75% relative humidity. The area is characterized with a mean annual sunshine of 2000 hours with about 5 hours mean daily sunshine and annual mean radiation of about 130 Kcal m^{-2}. These data were gathered from the Weather Station of the Faculty of Agricultural Sciences, Ekiti State University, Nigeria (Pessyl Instruments, Austria Inc.). The vegetation type in the area is primarily an evergreen rainforest but gradually changing to derived savannah due to intense cultivation and poor soil management practices by the rural dwellers in the surrounding communities/settlements. The present vegetation comprises of various bush regrowth, grasses and creepers and arable crops grown in the environment include yam, cassava, maize and vegetables. The dumpsite at Ilokun, Ado-Ekiti has been active for close to two decades and takes waste from various sections of the Ado-Ekiti community, ranging from household waste, market waste, agricultural waste, automobile mechanic workshop waste, industrial wastes and so on.

B. Soil Sampling

Surface soil samples were taken in triplicates, after removing the overlying wastes at 0 m (centre of the dumpsite), 25 m N (North of the dumpsite), 50 m S (South of the dumpsite), 75 m E (East of the dumpsite), 100 m W (West of the dumpsite) and 125 m SE (Southeast of the dumpsite) at a depth not more than 15 cm during the wet and dry seasons using soil auger. A background soil sample was also taken in triplicate at similar depth from an uncultivated land at 1 km SW (Southwest) away from the dumpsite, to serve as the control sample. The samples were carefully handled right from the field to the end of the laboratory analysis to avoid contamination. Samples were air-dried, crushed gently and screened through a 2 mm sieve and made ready for laboratory for analysis.

C. Analytical Procedures

The soil particle distribution analysis was done using the Bouyoucos Hydrometer method and textural classes determined in reference to USDA textural triangle. The pH of the soil was determined in water at 1:1 soil/water mixture using pH meter. The total nitrogen was analyzed by the modified Micro-Kjeldhal digestion procedure, available phosphorus were extracted by Bray 1-P method, wet combination Walkley-Black method was employed in the determination of organic carbon and exchangeable bases extracted from the soils using neutral normal ammonium acetate as described by [7]. Air-dried soil samples weighing 0.50 g of 2 mm particle size were digested using 20 ml freshly prepared aqua regia (1:3 HNO_3: HCl) on a hot plate for 3 hours, and then evaporated and the concentrations of metals analyzed [8]. The total concentrations of Cd, Cr, Cu, Fe, Pb, Mn and Ni in supernatants were then determined using an Atomic Absorption Spectrophotometer (Alpha 4 model) and the means were calculated.

D. Pollution Assessment Indices

In this study, five different indices or criteria were used to properly assess the heavy metals pollution in the environment of dumpsite at Ilokun, Ado-Ekiti, Nigeria:

CF

This gives an indication of the level of contamination in the environment and it is measured as a ratio of the measured toxic elements' concentration in the sample to their corresponding concentrations in the natural background sample. It is estimated by equation proposed by [9]:

$$CF = C_{sample} / C_{background}$$

where, C_{sample} = mean metal concentration in polluted soils, $C_{background}$ = mean natural background value of that metal. And, CF < 1 indicates to low metal contamination, $1 \leq CF \leq 3$ indicates moderate metal contamination, $3 \leq CF \leq 6$ indicates considerable metal contamination, and CF > 6 indicates very high contamination.

PLI

The number of times the metal concentration in the sampled soil exceeded the average natural background concentration is indicated by the PLI value and it reveals the total comprehensive degree of heavy metal toxicity in a given sample [2]. The PLI have been computed in several studies to estimate the pollution status of heavy metals and suggested necessary action to be taken. Using the approach of [10], [2], [11] obtained PLI as a CF of each metal with respect to the natural background status in the soil using equation:

$$PLI = [CF_1 \text{ x } CF_2 \text{ x } CF_3 \text{ x } \ldots\ldots\text{x } CF_n]^{1/n}$$

where n = number of metals = 7

According to [12], [13], the scale of PLI in indicating heavy metal pollution is PLI value ≤ 1 indicates heavy metal loads near background level and PLI value > 1 indicates soil pollution.

Modified Degree of Contamination (mC_d)

The generalized pollution index equation of [8] for overall degree of contamination was modified and expressed as the sum of all CFs for a given set of heavy metals divided by the number of analyzed heavy metals. [14], mathematically expressed it as below and gradation for descriptive classification presented in Table I:

$$mC_d = \frac{\sum_{i=1}^{i=1} C^i f}{n}$$

where, n = number of analyzed elements, i = i^{th} element, C_f= contamination factor.

EF

EF is an indication of the degree of pollution or contamination. [2], [15], [16] used EF in their separate studies to evaluate the relative contributions of natural and anthropogenic heavy metal inputs to soils, even though [17] suggested that high EF values does not serve as a reliable pointer indicating the extent of human interference with the global environment. Reference [18] suggested that the contribution of the anthropogenic sources of heavy metal increases simultaneously with the EF values. In this study, EF is calculated using the modified formula based on the suggested equation by [19], as:

$$EF = \frac{C_n(sample)/C_{ref}(sample)}{B_n(background)/B_{ref}(background)}$$

where, C_n (sample) = the content of the examined element in the examined environment, C_{ref} (sample) = the content of the reference element in the examined environment, B_n - (background) = the content of the examined element in the background environment, B_{ref} (backround) = the content of the reference element in the background environment.

According to [20], the reference element is a geochemically characteristic element that is present in high concentration in the environment but without having synergistic or antagonistic effects on the examined element. Most commonly used reference elements are Sc, Mn, Al, Ti and Fe [2], [21]. In this study, there was seasonal variation in the concentrations of the evaluated heavy metals. Consequently, Ni and Fe were regarded as reference elements, respectively for the dry season and the wet season heavy metal pollution assessments in the soils around the dumpsite at Ilokun, Ado-Ekiti. The five recognized and interpreted contamination categories on the basis of EF suggested by [17] are presented in Table II.

TABLE I
GRADATIONS FOR DESCRIPTIVE CLASSIFICATION OF MODIFIED DEGREE OF CONTAMINATION (MC_D) [14]

mC_d Value	Designation of quality
$mC_d < 1.5$	Nil to very low degree of contamination
$1.5 \leq mC_d < 2$	Low degree of contamination
$2 \leq mC_d < 4$	Moderate degree of contamination
$4 \leq mC_d < 8$	High degree of contamination
$8 \leq mC_d < 16$	Very high degree of contamination
$16 \leq mC_d < 32$	Extremely high degree of contamination
$mC_d \geq 32$	Ultra high degree of contamination

TABLE II
CONTAMINATION CATEGORIES ON THE BASIS OF EF [17]

EF Value	Designation of quality
EF < 2	Deficiency to mineral
EF = 2 – 5	Moderate enrichment
EF = 5 – 20	Significant enrichment
EF = 20 – 40	Very high enrichment
EF > 40	Extremely high enrichment

Geoaccumulation Index (I_{geo})

Geoaccumulation index, I_{geo} indicates the degree of pollution of soil with regards to the geochemical background concentrations of the polluting heavy metals. The I_{geo} values were calculated using the equation first proposed by [22], by multiplying the geochemical background concentrations of the metals each time by a constant, 1.5 in order to allow content fluctuations of a given substance in the environment as well as very small anthropogenic influences [23]. Geoaccumulation index is mathematically expressed below and distinguished classes shown in Table III:

$$I_{geo} = \log_2 C_n/1.5\,B_n$$

where, C_n = concentration of the examined element in the examined environment, and B_n = geochemical background of a given element in reference environment.

TABLE III
DISTINGUISHED CLASSES OF GEOACCUMULATION INDEX OF HEAVY METALS [24]

I_{geo} class	I_{geo} value	Designation of quality
0	$I_{geo} \leq 0$	Unpolluted
1	$0 < I_{geo} < 1$	Unpolluted to moderately polluted
2	$1 < I_{geo} < 2$	Moderately polluted
3	$2 < I_{geo} < 3$	Moderately to strongly polluted
4	$3 < I_{geo} < 4$	Strongly polluted
5	$4 < I_{geo} < 5$	Strongly polluted to extremely polluted
6	$5 < I_{geo}$	Extremely polluted

E. Statistical Analysis

Raw data were used for statistical analysis using Excel Microsoft 2013 Package. Means of heavy metals concentration were determined and relationships between metals concentrations were established using Pearson's correlation coefficient in a two-tailed test ($p < 0.01$ and 0.05).

III. RESULTS AND DISCUSSION

A. Distribution of Heavy Metals in Soils at Ilokun Dumpsite

The average metal concentrations in the soils in and around the Ilokun Dumpsite and the reference soil (background) are presented in Tables IV and V for the dry and wet seasons, respectively. The background concentration of the examined heavy metals are generally lower than those recorded in soils in and around the dumpsite at both dry and wet seasons, an indication that the metals are mainly from the anthropogenic sources rather than lithogenic sources.

During the dry season, the heavy metals distribution generally follow a similar trend, with the point of contamination (0 m) having the highest concentration and decreases with sampling distance except for Ni that had the least concentration at 0 m. There were also intermittent increases in metal concentrations at certain sampling distances than the preceding ones. The overall mean concentration of the heavy metals in the order: Ni > Mn > Pb > Cr > Cu > Cd > Fe. All the metals were below the intervention values stipulated for soils in Nigeria by [25] although Cd and Ni were above the targeted values of 0.80 and 35.00 mg kg^{-1} respectively.

During the wet season, there is no particular trend in metal distribution with an increase in distance from point of contamination (0 m) although it (0 m) recorded the highest metal concentrations except Fe that had the highest concentration at 50 m sampling distance. Such variable pattern was also reported for topsoil within the vicinity of Ratcon Limestone quarry in South western, Nigeria [26]. The overall mean concentration of the metals is in order: Fe > Cr > Cu > Pb > Ni > Cd > Mn. All the metals were above the targeted values stipulated for soils in Nigeria and below the intervention values except Cr (810.94 mg kg^{-1}), Cu (329.06 mg kg^{-1}) and Fe (15206.95 mg kg^{-1}) that are above the [25] values of 380, 190 and above 5000 mg kg^{-1} respectively for the metals.

TABLE IV
AVERAGE HEAVY METALS CONCENTRATION VALUES (MG KG^{-1}) IN THE BACKGROUND SOILS AND ILOKUN DUMPSITE SOILS IN THE DRY SEASON

Sample Distance (m)	Cd	Cr	Cu	Fe	Pb	Mn	Ni
Background	1.59	4.41	3.76	0.84	5.18	4.74	4.42
0	10.60	84.17	44.33	1.27	90.27	175.43	141.50
25 N	7.10	66.27	22.60	1.21	84.77	137.33	169.10
50 S	8.00	65.46	20.17	1.20	77.40	134.83	172.27
75 E	7.93	78.27	18.10	0.89	62.27	158.33	163.89
100 W	5.93	68.17	13.17	0.81	71.17	123.83	170.10
125 SE	8.17	69.77	21.43	1.00	67.17	29.82	166.89
Mean (n = 6)	7.96	72.02	23.30	1.06	75.51	126.60	163.96

TABLE V
AVERAGE HEAVY METALS CONCENTRATION VALUES (MG KG^{-1}) IN THE BACKGROUND SOILS AND ILOKUN DUMPSITE SOILS IN THE WET SEASON

Sample Distance (m)	Cd	Cr	Cu	Fe	Pb	Mn	Ni
Background	10.67	55.17	32.50	6425.00	125.00	5.50	35.50
0	12.50	1241.67	769.00	10000.00	805.00	12.50	57.50
25 N	10.60	323.33	320.00	6676.67	202.33	10.40	32.17
50 S	5.57	1055.67	47.33	41233.33	155.67	10.57	51.07
75 E	10.67	863.33	680.00	9366.67	157.00	5.63	37.50
100 W	10.53	763.33	105.00	10850.00	153.33	5.33	41.16
125 SE	5.57	618.33	53.00	13115.00	105.00	5.33	46.20
Mean (n = 6)	9.24	810.94	329.06	15206.95	263.06	8.29	40.60

TABLE VI
CF, PLI AND MODIFIED DEGREE OF CONTAMINATION (MC_D) OF HEAVY METALS IN ILOKUN DUMPSITE SOILS DURING THE DRY SEASON

Sample Distance (m)	Cd	Cr	Cu	Fe	Pb	Mn	Ni	PLI	mC_d
0	6.67	19.09	11.79	1.51	17.43	37.01	32.01	12.50	17.93
25 N	4.47	15.03	6.01	1.44	16.37	28.97	38.26	10.10	15.79
50 S	5.03	14.84	5.36	1.43	14.94	28.45	38.98	9.95	15.58
75 E	4.99	17.75	4.81	1.06	12.02	33.40	37.08	9.47	15.87
100 W	3.73	15.46	3.50	0.96	13.74	26.13	38.48	8.30	14.57
125 SE	5.14	15.82	5.70	1.19	12.97	6.29	37.76	7.78	12.12
Mean	5.01	16.33	6.20	1.27	14.53	26.71	37.10	9.68	15.31

TABLE VII
CF, PLI AND MODIFIED DEGREE OF CONTAMINATION (MC_D) OF HEAVY METALS IN ILOKUN DUMPSITE SOILS DURING THE WET SEASON

Sample Distance (m)	Cd	Cr	Cu	Fe	Pb	Mn	Ni	PLI	mC_d
0	1.17	22.51	23.66	1.56	6.44	2.27	1.62	4.21	8.46
25 N	0.99	5.86	9.85	1.04	1.62	1.89	0.91	2.08	3.17
50 S	0.52	19.14	1.46	6.42	1.25	1.92	1.44	2.28	4.59
75 E	1.00	15.65	0.55	1.46	1.26	1.02	1.06	1.50	3.14
100 W	0.99	13.84	3.23	1.69	1.23	0.97	1.16	1.94	3.30
125 SE	0.52	11.21	1.63	2.04	0.84	0.97	1.30	1.54	2.64
Mean	0.87	14.70	6.73	2.37	2.11	1.51	1.25	2.26	4.22

B. CF, PLI and Modified Degree of Contamination (mC_d)

In this study, the results of CF, PLI and modified degree of contamination (mC_d) for the soils in and around Ilokun Dumpsite were presented in Tables VI and VII, respectively, for the dry and wet seasons. In the dry season, the heavy metals CFs ranged from moderate contamination (Fe – 1.06) to very high contamination (Ni – 38.98) across the various sampling distances except at 100 m, where Fe gave a low CF of 0.96. Generally, the metals shown a decreasing contamination with an increasing sampling distances except on few occasions where the CF values shot-up drastically and went down again mostly at 50 m and 75 m sampling points for Cd, Cr and Mn. Only Ni exhibited a reverse trend among the metals investigated. The soil at the dumpsite centre (0 m) recorded the highest and very high CFs for all the metals except Ni. These very high CF values at this point could be attributed to the fact that 0 m is the primary point of contact of these heavy metals in the soils in and around the dumpsite at

Ilokun. The increasing trend of metals contamination during the dry season in the studied dumpsite environment on the basis of average CF per metal is in the order of Fe < Cd < Cu < Pb < Cr < Mn < Ni with Ni having the highest CF value. Reference [2] reported a similar trend for soils within the auto-mechanic workshops in Ikare-Akoko, Ondo State, Nigeria.

In the wet season (Table VII), the CF values of the heavy metals across the various sampling points ranged from 0.52 (Cd at 50 and 125 m) to 23.66 (Cu at 0 m), indicating low contamination to very high contamination of the soils in the Ilokun Dumpsite environment. The metals generally had higher CF values at the 0 m (point of contamination) just like in the dry season except for Fe with the highest CF value (6.42) recorded at 50 m sampling point. The average CF per metal is in increasing order of Cd < Ni < Mn < Pb < Fe < Cu < Cr with Cd having the least CF value and Cr having the highest during the wet season. Hence, Cr and Cu were at very high contamination level, Fe, Pb, Mn and Ni were at moderate contamination level and only Cd (0.87) ranked at low contamination level in the Ilokun Dumpsite soils. The indiscriminate disposal of wide range of wastes in the studied dumpsite could be responsible for the generally high CF values recorded.

The PLI for the soils in and around the environment of the dumpsite at Ilokun ranged from 7.78 – 12.50 during dry season (Table VI) and 1.54 – 4.21 during the wet season (Table VII), both indicating a decreasing trend away from the point of contamination (0 m). The PLI values were all greater than unity (1), implying that the soils in the studied dumpsite environments were polluted with the investigated heavy metals, a situation that needed to be checked in order to avoid further environmental deterioration. The PLI values also suggest to certain degree, that the heavy metals' input were from the anthropogenic sources from different deposited wastes.

The modified degree of contamination (mC_d) values in the soils ranged from 2.64 (Table VII) to 17.93 (Table VI) with points of contamination (0 m) having the highest values and 125 m sampling points having the least values, both at dry and wet season. At 0 m during the dry season, the soil was classified to be of extremely high degree of contamination. Whereas, at other sampling points, the soils were graded to be of very high degree of contamination class with an overall mean of 15.31. During the wet season, the soils were generally classified to be of moderate degree of contamination except soil at 0 m, having mC_d value of 8.46 indicating a high degree of contamination. The modified degree of contamination of the soils was generally higher during the dry season compared to wet season. This could be due to the fact that metals reactions with oxides and cementing agents bounding the soil particles are thermodynamically unstable as season changes, which either influenced the release or retention of metal elements in the soil [27].

C. EF and Geoaccumulation Index (I_{geo})

The values of the calculated EF and I_{geo} for the soils in and around the Ilokun Dumpsite during the dry and wet seasons were shown in Tables VIII– XI. The result indicated that during the dry season, the soils were deficiently enriched with the assessed heavy metals as the EF values were all less than 2 (Table 8). EF values less than 2 have been reported by [28] for interior coastal lowland soils of the southwestern, Nigeria. The soils also exhibited similar enrichment level by the heavy metals during the wet season (Table IX) except for Cr and Cu, having overall EF mean values of 7.90 and 6.42, respectively, indicating significant enrichment levels of these heavy metals in the soils in and around the Ilokun Dumpsite. Reference [21] reported similarly high EF values for soils surrounding the Meyduk tailing dam in Iran. This implies that, the dumpsite environs are exposed to sources of pollution leading to environmental toxicity of these heavy metals particularly Cr, presenting a great health risk even at low concentration [29].

The geoaccumulation (I_{geo}) values in the Ilokun Dumpsite soils during the dry and wet seasons (Tables X and XI, respectively) shown that the soils in and around the studied dumpsite were within the I_{geo} Class 1 ($0 < I_{geo} < 1$), indicating unpolluted to moderately polluted soils with the assessed heavy metals. The positive I_{geo} values recorded suggest that the heavy metals contamination in the Ilokun Dumpsite soils resulted mainly from anthropogenic sources considered to emanate from indiscriminate refuse dumping rather than from the lithological sources (parent materials) that formed the soils. Reference [2], [28] in their related studies also reported a Class 1 I_{geo} for the investigated heavy metals.

D. Correlation Matrix

TABLE VIII
EF OF HEAVY METALS IN ILOKUN DUMPSITE SOILS DURING THE DRY SEASON

Sample Distance (m)	Cd	Cr	Cu	Fe	Pb	Mn	Ni
0	0.17	0.48	0.29	0.04	0.44	0.94	1.00
25 N	0.12	0.39	0.15	0.04	0.43	0.76	1.00
50 S	0.14	0.38	0.14	0.04	0.39	0.73	1.00
75 E	0.13	0.48	0.13	0.03	0.33	0.91	1.00
100 W	0.10	0.47	0.09	0.03	0.36	0.68	1.00
125 SE	0.14	0.49	0.15	0.03	0.34	0.17	1.00
Mean	0.13	0.45	0.19	0.04	0.38	0.70	1.00

TABLE IX
EF OF HEAVY METALS IN ILOKUN DUMPSITE SOILS DURING THE WET SEASON

Sample Distance (m)	Cd	Cr	Cu	Fe	Pb	Mn	Ni
0	0.75	14.42	15.08	1.00	4.05	1.45	1.04
25 N	0.96	5.63	6.28	1.00	1.52	1.81	0.87
50 S	0.08	2.98	0.23	1.00	0.19	1.23	0.22
75 E	0.69	10.72	14.25	1.00	0.85	0.70	0.72
100 W	0.59	8.18	1.90	1.00	0.71	0.57	0.69
125 SE	0.26	5.48	0.80	1.00	0.40	0.47	0.64
Mean	0.56	7.90	6.42	1.00	1.29	1.04	0.70

In order to minimized possible biasness that might emanate from mean concentration values of the heavy metals, the raw concentration data were used to calculate the Pearson correlation coefficients between the various metals investigated and shown in Table XII for both dry and wet seasons. During the dry season, the metals generally correlated positively at varying degrees ranging from weak to strongly significant correlation at $P < 0.05$ and 0.01 except for Ni that is negatively correlated with all other metals. At wet season, positive significant correlation at $P < 0.05$ were commonly recorded between the heavy metals except Fe and Ni that negatively correlated with Cd (r = -0.689*), Cu (r = -0.481), Pb (r = -0.213) and Cd (r = -0.141), respectively. The positive correlation exhibited by most metals indicates strong links between them, which possibly reflect their common origin. The negative correlation exhibited mainly by Ni and Fe at certain sampling distances/points suggests input of these metals from a non-point source.

TABLE X
GEOACCUMULATION INDEX (I_{GEO}) OF HEAVY METALS IN ILOKUN DUMPSITE SOILS DURING THE DRY SEASON

Sample Distance (m)	Cd	Cr	Cu	Fe	Pb	Mn	Ni
0	4.48×10^{-3}	2.33×10^{-7}	7.98×10^{-5}	2.97×10^{-1}	8.74×10^{-7}	1.37×10^{-13}	7.47×10^{-12}
25 N	2.82×10^{-2}	6.04×10^{-6}	8.11×10^{-3}	3.16×10^{-1}	2.05×10^{-6}	8.45×10^{-11}	5.00×10^{-14}
50 S	1.79×10^{-2}	6.97×10^{-6}	4.10×10^{-2}	3.20×10^{-1}	6.41×10^{-6}	1.30×10^{-10}	2.85×10^{-14}
75 E	1.85×10^{-2}	6.87×10^{-7}	2.12×10^{-2}	4.26×10^{-1}	6.66×10^{-5}	2.45×10^{-12}	1.29×10^{-13}
100 W	5.10×10^{-2}	4.26×10^{-6}	6.02×10^{-2}	4.64×10^{-1}	1.68×10^{-5}	8.27×10^{-10}	4.18×10^{-14}
125 SE	1.65×10^{-2}	3.20×10^{-6}	1.04×10^{-2}	3.87×10^{-1}	3.09×10^{-5}	6.54×10^{-3}	7.53×10^{-14}
Mean	2.28×10^{-2}	3.57×10^{-6}	2.35×10^{-2}	3.68×10^{-1}	2.06×10^{-5}	1.09×10^{-3}	1.24×10^{-12}

TABLE XI
GEOACCUMULATION INDEX (I_{GEO}) OF HEAVY METALS IN ILOKUN DUMPSITE SOILS DURING THE WET SEASON

Sample Distance (m)	Cd	Cr	Cu	Fe	Pb	Mn	Ni
0	3.90×10^{-1}	1.51×10^{-8}	5.99×10^{-9}	2.87×10^{-1}	5.78×10^{-3}	1.60×10^{-1}	2.70×10^{-1}
25 N	4.50×10^{-1}	9.18×10^{-3}	3.79×10^{-4}	4.35×10^{-1}	2.74×10^{-1}	2.20×10^{-1}	4.90×10^{-1}
50 S	6.60×10^{-1}	2.24×10^{-7}	3.12×10^{-1}	5.87×10^{-3}	3.69×10^{-1}	2.20×10^{-1}	3.20×10^{-1}
75 E	4.50×10^{-1}	3.64×10^{-6}	5.33×10^{-8}	3.11×10^{-1}	3.74×10^{-1}	4.40×10^{-1}	4.30×10^{-1}
100 W	4.50×10^{-1}	1.55×10^{-5}	7.53×10^{-2}	2.58×10^{-1}	3.65×10^{-1}	4.60×10^{-1}	4.00×10^{-1}
125 SE	6.60×10^{-1}	1.27×10^{-4}	2.70×10^{-1}	1.95×10^{-1}	5.11×10^{-1}	4.60×10^{-1}	3.50×10^{-1}
Mean	5.10×10^{-1}	1.55×10^{-3}	1.10×10^{-1}	2.49×10^{-1}	3.17×10^{-1}	3.30×10^{-1}	3.80×10^{-1}

IV. CONCLUSION

Surface soils in and around Ilokun Dumpsite have average metal concentrations generally higher than the background contents during the dry and wet seasons with no particular trend of distribution and were below the stipulated intervention levels except Cr (810.94 mg kg^{-1}), Cu (329.06 mg kg^{-1}) and Fe (15206.95 mg kg^{-1}) during the wet season. Employing the results of the pollution indices, soils in and around the Ilokun Dumpsite could be classified as heavy metals polluted or contaminated soils of concern using CF, PLI and modified degree of contamination (mC_d) as pollution assessment tools but as unpolluted and deficiently enriched soils when assessed with geoaccumulation index (I_{geo}) and EF, respectively, with the exception of Cr (7.90) and Cu (6.40) during the wet season. All the heavy metals assessed were indicated to be basically from a similar source of anthropogenic inputs emanating from indiscriminate dumping of refuse at Ilokun Dumpsite except in the cases of Fe and Ni at certain points.

RECOMMENDATION

This study assessed the degree of heavy metal pollution in surface soils in and around the Ilokun Dumpsite in Ado-Ekiti, Nigeria using pollution indices. Since the soils were having certain heavy metal contents above intervention levels in addition to the polluted state by the heavy metals, it is recommended that soil remediation should be carried out on the dumpsite and its environs before the pollution levels are escalated. Modern waste disposal facilities where proper sorting and recycling would be possible in an environmentally sound manner, should be put in place by the relevant authorities and appropriate waste disposal sites be chosen to avoid the deleterious effects of indiscriminate disposal of waste. Furthermore, monitoring and studies of the contents of these heavy metals should be carried out in the nearest future to ascertain the long-term effects of anthropogenic impact and heavy metal bioavailability.

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