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ABSTRACT

The study assessed the ecological risk and polluting load of heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) in surface soils within Bori Urban. The composite soil samples collected from different locations were prepared and atomic absorption spectrophotometer (AAS) was used for the analysis of the heavy metals. From the results of the analysis, the mean concentrations (mg/kg) of the heavy metals decreased in the order Cu (37.42) > Ni (34.06) > Cr (28.66) > Zn (7.75) >Pb (2.03) > Cd (0.89). The mean concentrations of Cd, Cu, and Ni were above USEPA soil guidelines and world unpolluted soil average, while those of Pb and Zn were below. The mean concentrations of the heavy metals from the study locations were all above that of the control location. The findings indicated that the urban soils of the study were loaded with heavy metals due to anthropogenic activities. The anthropogenic percentage input was in the range of 63.92 - 89.13 above 50% indicating anthropogenic origin of the heavy metals in soils of the study area. The results of ecological risk index (Er) indicated that Cd with Er (467.40) contributed up to 94.51% to the potential ecological risk index (RI) while Zn (0.78) contributed 0.16%. The heavy metals under study posed highly strongly potential ecological risk with RI value of 494.56 to the Bori urban soil due to anthropogenic activities. The ANOVA result of FCal 6.42 > [F(5.30) = 2.53, P< 0.05)] revealed significant differences between the soil sample mean values due to different anthropogenic pollution sources with different loads of heavy metals as pollutants. The Omega Squared (w2) value of 0.52 > 0.14 showed very strong interactive relationship among the heavy metals to bring about high level of ecological potential risk of the urban soils in the study area. Based on the findings, the surface soils have elevated load of heavy metals thereby posing ecological potential risk to Bori urban soils. Therefore, there should be periodic monitoring and environmental audit by relevant authorities to ensure good soil quality of Bori urban soil.

Keywords: Potential ecological risk, pollution load, Bori Urban, Anthropogenic Percentage input, contamination Factor.

1.0: **INTRODUCTION**

The heavy metals are important because of their potential toxicity to the environment and human beings. The role of heavy metals in urban soil system is becoming an issue of global concern (Roozbahani et al., 2015). Soil constitutes important component of rural and urban environments and the sources of the contaminants in urban soil majorly include natural occurrence derived from parent materials and human activities (James *et al.,* 2020).Anthropogenic inputs of urban soil pollution are associated with rapid and uncontrolled urbanization and industrialization. These sources according to Iwegbue *et al.,* (2013), are urban effluents, traffic emissions, fertilizer application, wastewater utilization in agricultural lands, manufacturing and construction activities, burning of fossil fuels, and vehicular emissions.

Heavy metal contents of urban soils are of major significance due to their non-degradable nature and ability to accumulate for long period of time. The studies carried out by Marcus *et al.,* (2017), Nwineewii and Nna, (2016) revealed that heavy metals exhibit certain metallic properties which distinguish them from other metals. These heavy metals are known to be toxic when they reach or exceed certain concentrations in food, water, soil and air, although some of them are very important to humans, animals and plants at trace levels. The presence of heavy metals in an environment alters the structure and functions of the ecosystem. This is attributed to the fact that their presence has effect or influence on the nature of the physical and chemical properties of urban soil.

The urban environmental quality is of vital importance as the majority of people now live in urban areas. As a result of continuous urbanization and industrialization in many parts of the world, metals are continuously released into the terrestrial environments which pose great threat to human health (Qiu, 2010).

Bori urban is one of the urban areas with various anthropogenic activities including electrical, clothing, jewelry, furniture shops, supermarkets, fuel stations, numerous automobile services and repair workshops. Increased artesian and automobile repair workshops which include auto mechanic, auto welding, auto electrician and auto painting units may create varieties of wastes which contain heavy metals in course of their daily operations. These wastes include used oil, and fluids, dirty shops rags, used parts, asbestos from brake pads and wastes from solvents used for cleaning parts which contain heavy metals that are dangerous to human and the environment (Liang *et al.,* 2011).

An ecological risk assessment is the process to evaluate the likeliness of an environment to be impacted due to the exposure to one or more environmental stressors (Sayadi, *et al.,* 2015). Ecological risk assessment is a systematic process for analyzing risk or likelihood of adverse effects to the ecology of an area in response to human activities. The concentrations of heavy metals can increase in the surface soils via human activities, resulting into contamination of urban soils.

Innumerable studies have been carried out in many cities around the world, investigating the heavy metal contents in urban soils. For instance, Salah, *et al.,* (2015) worked on heavy metals in urban soils in Baghdad city, Iraq, Mohammed *et al.,* (2015) worked on heavy metals in soils of Sirte city, Libya; Wang *et al.,* (2017) did work on heavy metals in urban soils within Suzhou city, China, all the findings of these investigations revealed elevated concentrations of heavy metals in urban soils. Sayadi *et al.,* (2015) embarked on the study of pollution index and ecological risk of heavy metals in the surface soils of Amir-Abad area in Birjand city, Iran; Omran (2016) worked on environmental modeling of heavy metals using pollution indices and multivariate techniques in the soils of Bahr El

Baqar, Egypt, the findings of these studies on heavy metals for the determination of the ecological risk, revealed high ecological risk at the surface soils.

In Nigeria, studies have equally been carried out on heavy metals in urban soils. Onwudike *et al.*, (2017) worked on heavy metals of Owerri soil; Ekwere *et al.* (2014) carried out a study on the distribution of heavy metals in urban soils; a case study of Calabar Area, South-Eastern Nigeria; Iwegbue *et al.*, (2013) carried out a study on the assessment of heavy metals contamination in soils around cassava processing mills in sub-urban areas of Delta State, Southern Nigeria; Edori and Kpee (2017) carried out a study on index models assessment of heavy metals pollution in soils within selected abattoirs in Port Harcourt, Rivers State, Nigeria. The findings of these researches revealed that the soil samples under study were highly contaminated or polluted with heavy metals. None of these studies investigated heavy metals in Bori urban surface soil, thereby creating a gap that needs to be filled. Studies concerning heavy metal contamination in urban soils are needed to develop strategies to protect urban environments and human health against long-term accumulation of heavy metals. The present study represents first attempt to assess ecological risk and pollution load of heavy metals in soils of Bori urban.

2.0: MATERIALS AND METHODS

2.1: Study Area

The study area consists of some selected locations in which high anthropogenic activities occurred within Bori urban. Bori urban is located at 4.67^0 North latitude, 7.36^0 East longitude and 201 meters elevated above sea level. Bori urban is in Khana Local Government Area of Rivers State, Southern Nigeria. Bori is the traditional headquarters of the Ogonis. Bori is a central point for commercial activities for the Ogonis, Opobo, Andoni, Annang in Akwa Ibom State and other ethnic groups from Niger Delta and other parts of the country.

Bori urban is surrounded by communities such as Zaakpon, Boue, Betem, Yeghe, Wiiyaakara, Kpong, Kaani and Kor which carry out different human activities in Bori urban. The Kenule Beeson Saro-Wiwa (Rivers State) Polytechnic is situated in Bori urban. Bori consists of vast land area with population of over 250,000.

2.2 Soil Sample Collection and Analysis

Soil samples were collected from seven (7) selected study locations at 10-15cm depth including the control location collected with the aid of a stainless-steel hand auger. Three soil samples from each sampling location were randomly collected to make a composite sample. The collected composite samples were stored in properly labeled polythene bags for analysis.

The soil samples were air-dried for 2 days, homogenized and sieved through a 2mm mesh to obtain uniform size. The soil samples were subjected to wet digestion using nitric-perchloric acid method in line with the works of Ogunkunle *et al.* (2013) and Oladeji *et al.* (2016). 2 grams of each sample were weighed into a 50ml beaker, then added to the sample were 20mls and 10mls of concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$) respectively for 30-45 minutes at 60^oC. The solution was allowed to cool at room temperature, filtered into a 50ml volumetric flask and made up to the

50ml mark with distilled water. The digested samples were used for determination of concentration of the heavy metals (Cd, Cr, Cu, Ni, Pb,and Zn) using the Atomic Absorption Spectrophotometer (AAS).

2.4: Pollution Indices for Heavy Metals Analysis

To determine the status of contamination in the study area the following pollution indices were used:

Contamination Factor (Cf)

Contamination Factor (Cf) was used to indicate the environmental contamination of a specific metal in the study sample. This (Cf) factor was calculated using the equation by Hamid *et al*., (2016) expressed as

$$Cf = \frac{(Sample}{(ref} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \quad (1)$$

Where:
Cf represents contamination factor (mg/kg)
C Sample represents average metal concentration in the study sample (mg/kg).
C_{ref} represents the same metal concentration in the reference sample (mg/kg).

The Contamination Factor (Cf) as classified by Hamid et al., (2016) is indicated in Table 1.

Table 1: Classification of Contamination Factor

Contamination Factor (CF)	Description
CF < 1	Low contamination
1 < CF < 6	Moderate contamination
3 < CF < 6	High contamination

Source: Hamid *et al.,* (2016)

2.5: Quantification of Anthropogenic Input for Heavy Metals

The quantification of anthropogenic input for each heavy metal is calculated by means of the equation described by Iwegbue *et al.,* (2013),

$$\%\, anthropogenic\ input\ for\ heavy\ metal = \frac{X - X_C}{X} \times \frac{100}{1} \ldots. (2)$$

Where X = metal content representing the world average shale value.
Xc = average concentration of heavy metal in the soil of the sampling location.

2.6: Potential Ecological Risk Assessment

The potential environmental risk factor was calculated to assess the contamination of heavy metals in soil and the ecological and environmental effects of heavy metals (Riyad *et al.,* 2015). The ecological risk index (RI) was calculated according to equations (3) and (4) (by Naeni *et al.,* 2019).

These pollution indices have their various formulae for calculation as well as their standards for classification.

E_r = T_i x C_f …………………………..…… (3)

Where

E_r = Ecological risk factor

T_i = Toxic response factor for the selected heavy metal indicated in Table 3.4

C_f = Contamination factor

Table 2: Toxic response factor

Element	Cr	Cd	Cu	Mn	Ni	Pb	Zn
Toxic response factor	2	30	5	1	5	5	1

Source: Ripin*et al.*, (2014)

R1 = $\sum E_r$ ………………………………………… (4)

Where:

R1 =Potential ecological risk index, Er= Ecological risk factor.

The potential ecological risk index is defined, according to Mugosa *et al.*, (2016), as the sum of the risk factors (equation 3). The classification of potential ecological risk factors is classified as shown in Table 3.

Table 3: The potential ecological risk factor

Risk level	Ecological risk factor (Er) value	Risk degree	Potential ecological risk value (RI)
Low	Er< 40	Low	150 < RI
Moderate	40 $\leq$Er< 80	Moderate	150 < RI < 300
Considerable	40 $\leq$Er< 160	Considerable	300 < RI < 600
High	160 $\leq$Er< 320	Very high	R1 > 600

Source: Naeini*etal.*, (2019)

2.7: Statistical Analysis

The data were statistically analyzed using ANOVA to detect any significant difference between the soil sample means of different sampling locations of the study area. Omega squared (W^2) by Huck (2012) was used to determine whether the various heavy metals interact significantly with each other, with the equation as

$$Co^2 = \frac{SS_{betwen}}{SS_{between} + SS_{within}} \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where:

W^2 = Omega squared

$SS_{between}$ = Between sample means

SS_{within} = Within sample means

Hunk (2012) described the levels of interaction based on the calculated value of w^2 as shown in Table 4.

Table 4: Different levels of interactive relationship

Value of Mega squared (w^2)	Level of interactive relationship
0.01 – 0.05	Small interactive relationship
0.06 – 13	Medium interactive relationship
$\geq$ 14	Large interactive relationship

Source: Huck (2012)

3.0: RESULTS AND DISCUSSION

3.1: Mean Concentration of Heavy Metals

Descriptive statistics of the concentrations (mg/kg) of heavy metals in soils from the results of the analysis are presented in Table 5. The mean concentrations of the heavy metals decrease in the order Cu (37.42) > Ni (34.06) > Cr (28.66) > Zn (7.75) >Pb (2.03) > Cd (0.89). The mean concentrations of Cd (0.89 mg/kg), Cu (37.42 mg/kg) and Ni (34.06 mg/kg) exceed the USEPA soil guidelines, Cd (0.60 mg/kg), Cu (16mg/kg), Ni (16mg/kg) and the world average values for unpolluted soils which are for Cd (0.53), Cu (24) and Ni (34). The mean concentration of Cr (28.66 mg/kg) exceeded 25mg/kg for USEPA soil guideline and was below 83 mg/kg for world average value of unpolluted soil. The mean concentrations of Pb (2.03 mg/kg) and Zn (7.75 mgk/g) were below the USEPA guideline of Pb (35 mg/kg), Zn (110 mg/kg) and the world average values of unpolluted soil, Pb (44 mg/kg) and Zn (100 mg/kg). The mean concentrations of heavy metals are all above their mean concentrations of the control soil samples.

Results of the comparison with the soil guidelines and the world average values indicate that the surface soils of the study area were polluted by Cd, Cu and Ni. These findings are in agreement with the results reported on different urban soils conducted by Salah *et al.*, (2015), in Baghdad &Ekwere*et al.*, (2014) in Calabar. The mean concentrations of the heavy metals in the study were higher than those conducted by Garba and Abubakar (2018) on heavy metals in soils of Bauchi metropolis, Nigeria and lower compared to the study carried out by Sayadi*et al.*, (2015) on heavy metals in the surface soils of Birjand city, Iran.

Anthropogenic inputs of these heavy metals into the surface soils may be of different sources. According to Salah *et al.*, (2015) heavy metals like Cd can be ascribed with wear and tear of tyres in traffic movement. Cd is used in different anthropogenic activities such as in paints, pigments, electroplating and plastic stabilizer within the study area. From the results, the urban soils can be said to be polluted by Ni after its comparison with standards. According to Riyad*et al.*, (2015), the sources of Ni in urban soils are derived from traffic emission and industrial emission. The different types of detergents could be important sources of Ni in the urban soils. The elevated levels of these heavy metals in the study area may be attributed to the anthropogenic activities.

Table 5: Heavy Metals Concentrations (mg/kg) in Soils with the Soil Guidelines and the World Average Values of Unpolluted Soil

Heavy metal	Min	Max	Mean ± STD	Mean value of control soil	USEPA soil guidelines (Salah *et al.*, 2015)	World Average value of unpolluted soil (Alobaidy*et al.*, 2013)
Cadmium (Cd)	0.001	2.751	0.591 ± 0.10	0.001 ± 0.00	0.60	0.53
Chromium (Cr)	13.110	47.331	28.663 ± 3.51	4.204 ± 1.41	25	83
Copper (Cu)	19.201	67.131	37.418 ± 5.61	5.348 ± 2.85	16	24
Lead (Pb)	0.017	5.137	2.033 ± 1.64	0.220 ± 0.00	35	44
Nickel (Ni)	23.133	63.971	34.06 ± 4.73	7.151 ± 2.16	16	34
Zinc (Zn)	2.411	14.571	7.754 ± 3.98	2.477 ± 0.07	110	100

3.2: Contamination Factor (CF)

The Contamination Factor (CF) values for each measured heavy metals are presented in Table 6. The highest CF values for Cd were as follows, Motor Park (6.37), market area (4.35) and major roadside (3.76) which are of high contamination. For residential area with CF value (1.08) was of moderate contamination. School area and hospital area with CF value (0.10) each for Cd was low contamination. But Pb, Cr, Ni, Zn and Cu have the CF values which were of low contamination in all the land use areas of the study area. The CF values of the investigated heavy metals were higher than their CF values in the control sample. These results agree with the findings of the study by Mugosa*et al.*, (2016) which identified high CF values of Cd, Cu, Zn, Pb and Cr in their study locations. The CF values of these heavy metals whether low or high indicate the contamination of the soils in the study area as a result of anthropogenic activities.

Table 6: Contamination Factor Values for Heavy Metals.

Sampling Locations	Pb	Cr	Cd	Ni	Zn	Cu
Motor park	0.23	0.32	6.37	0.41	0.16	0.71
Major Roadside	0.16	0.21	3.76	0.32	0.11	0.48
Market Area	0.17	0.28	4.35	0.36	0.12	0.53
Residential Area	0.09	0.15	1.08	0.23	0.16	0.30
School Area	0.04	0.12	0.01	0.12	0.09	0.17
Hospital Area	0.03	0.07	0.01	0.18	0.09	0.12
Control Sample	0.01	0.01	0.00	0.01	0.05	0.01

3.3: Quantification of Anthropogenic Percentage Input of Heavy Metals

The percentage anthropogenic contributions for each heavy metal was determined and presented in the Table 7.

Table 7: Anthropogenic percentage input for Heavy Metals in sampling soils.

Sampling Locations		Heavy	Metals			
	Pb	Cr	Cd	Ni	Zn	Cu
Motor park	77.10	79.58	57.52	52.88	44.10	11.16
Major Roadside	84.40	86.48	74.95	64.54	60.92	74.33
Market Area	82.56	83.35	71.02	58.80	55.18	71.54
Residential Area	91.41	90.42	92.82	73.94	68.92	88.77
School Area	96.25	92.59	99.82	86.34	82.43	90.86
Hospital Area	97.24	95.61	99.82	78.99	82.13	93.63
Control Sample	98.90	99.48	99.98	98.82	90.09	99.48
Mean value	85.69	80.50	89.13	73.49	69.11	63.92

The amounts of Pb that were of anthropogenic origin in the sampling locations ranged from 77.10 to 97.24% with the mean value of 85.69%. All the sampling locations have anthropogenic Lead (Pb) fractions greater than 50%. Pb enters the environment due to its release from smelting, motor vehicle exhaust fumes and corrosion of Lead pipes. Sohban, (2018) reported in his study on the assessment of Pb and Ni contamination in the top soil of ring roads' green spaces in the city of

Hamadan, that Pb equally enters the environment during numerous anthropogenic activities which include mining, smelting and manufacturing and it can be toxic for human health.
The percentage of Cr in the sampling locations ranges from 79.58 to 95.61%, with the mean value of 77.48%. The percentage of Cr in all the sampling sites was greater than 50% indicating that the greater amount of Cr in the study sites was of anthropogenic origin. Barbieri (2016) pointed out in the study on the importance of enrichment factor (EF) and geo-accumulation index to evaluate the soil contamination, that variety of small scale industrial (anthropogenic) activities such as metal plating, anodizing, dyes, pigments, ceramic, glues, tanning, wood preserving and textiles contribute to the concentration of Cr in urban soils.
The mean value of Cd was 89.13% having the values ranging from 57.52 to 99.82% in the study sample soils. The percentage value of Cd in the sampling locations was more than 50%, pointing to the fact that anthropogenic activities contribute more fractions of Cd to the urban environment. Cd has been found in lubricating oil as part of many additives. The process of vulcanization releases Cd to the environment. The anthropogenic input of Cd could be as a result of lubricating oils and old tyres, other associated wastes as well as conveyor belts used in machine. The anthropogenic input of Cd observed in this study is similar to the finding reported for soils in some contaminated sites in urban areas (Iwegbue *et al.*, 2013). The percentage of Cd that was of anthropogenic origin was highest among the study metals.

The anthropogenic percentage input of Ni in these study sites ranges from 92.88 to 78.99%, with the mean value of 73.47%. The anthropogenic percentage input of Ni in all the sites was greater than 50%, revealing that Ni was more contributed to the urban environment by anthropogenic activities than lithogenic operation. The mean value (73.47%) of anthropogenic input observed in this study was lower than that observed by Iwegbue *et al.*, (2013) in their study with the value of77.6%. However, the mean value of 73.47% observed in this study was higher than the anthropogenic input of 25% found in the soils of urban areas, Iran (Fazeli *et al.,* 2018). It is generally noted that the anthropogenic source of Ni in the urban soils was domestic cleaning products with Ni in the following proportions: soap, 100 -700mg/kg; powdered detergents, 400 – 700mg/kg; and powdered bleach, 800mg/kg, proving to be important sources of Ni (Alobaidy & Mashhadi, 2013).

The amount of Zn that are of anthropogenic origin in these sites range from 44.10 to 82.13%, with the mean value of 69.11%. Majority of the study sites have anthropogenic Zn percentage greater than 50%. The major anthropogenic input of Zn in these sites are the attrition of motor vehicle tyres and rubber used as convey belts in the mills as well as the lubricating oil which is found as part of many additives as zinc dithiophosphates (Iwegbue *et al.*, 2013). The mean value of 69.11% is lower than the value of 82.0% reported for urban soil in Nigeria (Iwegbue *et al.,* 2013) and higher than the value of 2% in other part of the world (Fazeli *et al.,* 2018).

The percentage of Cu due to anthropogenic origin ranged from 61.66 to 93.63%, with the mean value of 63.92%. The anthropogenic percentage input of Cu in the study sites was greater than 50% revealing than Cu was majorly released to the urban soil due to anthropogenic activities. Cu, as reported by Sayadi *et al.,* (2015) is expensively utilized in electrical cables, cooking appliances, pipes, chemical factories, metal melting furnaces, pigments and fertilizers. Although it is one of the essential elements for humans, but its overdoses could lead to neurological complications, hypertension, liver and kidney dysfunctions and even death (Santos-Francis *et al.,* (2017). The

mean value of 63.92% was lower than the anthropogenic input of 86.4% reported by Iwegbue *et al.,* (2013) in urban soil of Nigeria but higher than the value 5% in urban soil of Tehran-Iran which Fazeli *et al.,* (2018) revealed in their study.
On a generally note it is observed that the selected heavy metals in this study are of anthropogenic origin since the anthropogenic percentages are more than 50% in all study locations.

3.4: Ecological Risk Index (ER) and Potential Ecological Risk Index (RI)

The Ecological Risk Index (Er) and potential ecological Risk Index (RI) values are presented in Table 8. It shows the single ecological risk factors (Er) of different heavy metals and their contributions to the potential ecological risk index (RI) of the urban soils. Looking at the table, the sequence of the ecological risk index of the heavy metals is in the order Cd (467.40) > Cu (11.60) > Ni (8.15) >Pb (3.65) >Cr (2.32) > Zn (0.78). Cd with the Er (467.40) possess the highest level of ecological risk, contributing up to 94.5% to the potential ecological risk index (RI) while Mn with Er (0.66) possess lowest level of ecological risk, contributing 0.13% to the potential ecological risk index (RI). The release of Cd into the urban soils of the study area causes great concern due to its high toxic response factor of 30 as shown in Table 2.

The release of Cd into the soils was accredited to the wear and tear of tyres and much traffic operations on the busy roads. According to report by Sun (2017), that Cadmium (Cd) was used as Cadmium covering to cover furniture, cars, trucks, industrial tools and various kinds of fasteners including bolts, nuts and nails. Similarly, the input of Cd into the urban soils of the study area can be attributed to the corrosion of batteries and metallic parts of radiators and cars. These results agree with the findings of other researchers on ecological risk assessment of heavy metals in their various study areas. Riyad *et al.,* (2015), He *et al.,* (2014) and Pei *et al.,* (2013) reported significantly high potential ecological risks in their studies, which were mainly due to high contribution of Cd load in the soils.

The values of potential ecological risk index (RI) for the study locations and the study area are presented in the Table 8. The sequence of potential ecological risk index (RI) is in the order of motor park (198.86) > market area (136.60) > major roadside (118.31) > residential area (36.02) > school area (2.31) > hospital area (2.21). From the result, motor park has the moderate risk level while the other study locations have low risk level. The value of the potential ecological risk index (RI) of the study area was 594.56 which was the considerable degree of risk. This result tends to negative the finding of the study carried out by Edori and Kpee (2017) on heavy metal pollution in soils within selected abattoirs in Port Harcourt. The finding of their study reveals that the heavy metals under study do not pose any ecological risk to the environment. Rather, the result of study agrees with findings of the studies by Bello *et al.,* (2016), and Riyad *et al.,* (2015). They all reported in their studies that heavy metals posed potential ecological risk to the environment, which is the case in this study with the RI value of 494.56, indicating an overall highly strong potential ecological risk to the study area.

Table 8: Ecological Risk Index (Er) and Potential Ecological Risk Index (RI) ofSoil Samples.

Sampling Locations	Ecological Risk Index (Er)							Potential Ecological Risk Index (RI)	
	Pb	Cr	Cd	Mn	Ni	Zn	Cu	RI	Grade
Motor Park	1.15	0.64	191.10	0.21	2.05	0.16	3.55	198.86	Moderate risk
Major Roadside	0.80	0.42	112.80	0.18	1.60	0.11	2.40	118.31	Low risk
Market Area	0.85	0.56	130.50	0.12	1.80	0.12	2.65	136.60	Low risk
Residential Area	0.45	0.30	32.40	0.06	1.15	0.16	1.50	36.02	Low risk
School Area	0.20	0.24	0.30	0.03	0.60	0.09	0.85	2.31	Low risk
Hospital Area	0.15	0.14	0.30	0.03	0.90	0.09	0.60	2.21	Low risk
Control Sample	0.05	0.02	0.00	0.03	0.05	0.05	0.05	0.25	Low risk
Total	3.65	2.32	467.40	0.66	8.15	0.78	11.60	494.56	Very high
% contribution of heavy metal to RI	0.74	0.47	94.51	0.13	1.65	0.16	2.35		

3.5: Statistical Analysis by ANOVA

The results of statistical analysis of the parameters using ANOVA are presented in Table 9.

Table 9: Summary of ANOVA of heavy metals from various sampling locations in surface soils

Source of variation	SS	df	MS	F-ratio	Critical value F(at 5% from the F-table)
Between sample means ($SS_{between}$)	217.95	(6-1) = 5	$\frac{217.55}{5} = 43.59$		
				$\frac{43.59}{6.79} = 6.42$	F(5,30) = 2.53
Within sample means (SS_{within})	203.84	(36-6) = 30	$\frac{203.84}{30} = 679$		
Total	421.79	35			

Ss = Sum of squares; df = degree of freedom; MS = Mean square.

The result indicated that the F – calculated value of 6.42 is greater than F – critical of 2.53 [F (5,30) = 2.53, $p < 0.05$]. This result shows that there are significant differences between the sample mean values of the surface soils from different study locations in the study area. The significant differences suggest that there are different anthropogenic pollution sources containing different loads of heavy metals as pollutants in the study area.

To ascertain whether the heavy metals interact significantly with each other to bring about pollution of the surface soils in the study area, Omega squared (w^2) was calculated and presented in Table 9. The calculated value of Omega squared (w^2) was 0.52 and greater than 0.14. The Omega squared value 0.52 > 0.14 revealed very strong interactive relationship among the heavy metals to bring about high level of ecological risk of the surface soils in the study area.

4.0: CONCLUSION

Ecological risk assessment and pollution load of heavy metals in soils within Bori urban were examined. Six heavy metals (Cd, Cr, Cu, Ni, Pb, and Zn) in different sampling locations were analyzed including the control location. From the results of the analysis, the mean concentrations of Cd, Cu, and Ni were above USEPA soil guidelines and the world average values while those of Pb and Zn were below the soil guidelines.

The mean anthropogenic percentage input for the heavy metals was between 63.92 and 89.13. It was observed that the selected heavy metals in this study were of anthropogenic origin, since the anthropogenic input percentages were more than 50%. These heavy metals under assessment posed potential ecological risk with the RI value of 494.56 which indicated highly strong potential ecological risk to the study area due to anthropogenic activities. The Omega squared (w^2) calculated value of 0.52 equally indicated strong interactive relationship of heavy metals as pollutants.

Based on the findings, the surface soils are contaminated with heavy metals, thereby posing ecological potential risk to Bori urban soils. Therefore, this study recommends that, there should be periodic monitoring and environmental audit by the relevant environmental authorities to enhance good soil quality of Bori urban soil.

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