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Assessment of some heavy metals contamination in the soil of river Niger floodplain at Jebba, central Nigeria

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Abstract: The assessment of heavy metal contaminants: Mn, Cr, V, Cu, Pb, Zn and Ni, was conducted on River Niger Floodplain soil at Jebba, Central Nigeria using Contamination Factor (Cf), Factor (AF), Enrichment Factor (EF), Geo-accumulation Index (Igeo) and Degree of Contamination (Cdeg). Random sampling method was adopted cutting across the entire floodplain and the samples were subjected to Inductively Coupled Plasma Mass Spectrometry (ICP/MS) and X-Ray Fluorescence (XRF) methods of analyses. The computed results from the contamination indexes revealed an average AF value of 2.2, 0.8, 0.6, 1.7, 0.2, 0.5 and 1.3 for Mn, Cr, V, Cu, Pb, Zn and Ni respectively. The respective average of EF is: 1.1, 0.5, 0.2, 0.6, 0.1, 0.2 and 0.4. The average Igeo are generally <1. The degree of contamination ranges from low to moderate (2.5 to 14.2). The Cf shows that the soil samples are moderately contaminated with Mn, Cu and Ni (range=1.3 to 2.2) while Cr, V, Pb, and Zn show low contamination factor (range=0.2 to 0.8). Results also show that the source of contamination of Mn, Cu and Ni are by the various anthropogenic activities in the area and the influence of geogenic processes is prevalent on Cr, V, Pb and Zn in the soil samples.

Key words: contamination, geo-accumulation, Jebba, metal.

1. INTRODUCTION

Heavy metals in the natural environment might be toxic to man and his environment when they exceed certain prescribed limit. These metals, once they get into food-chain may cause several diseases to plants, animals and human beings that feed on them. The rate at which people die today of several diseases could be traced back to the ingestion of heavy metal contaminated food and water which might have originated from contaminated/polluted soil either by natural or artificial sources. Reports have shown that Cd, Cr, Pb, Zn, Fe and Cu pose potential hazard and occurrences in contaminated soils. Agricultural practices, industrial activities and Vehicle exhaust emit these metals, consequently increasing their level in the soil (Mmolawa et al. 2011; Akoto et al. 2008; Ghrefat and Yusuf, 2006; Alloway, 1995).

The influence of man and animals (agricultural practice) also play a major role in the condition of the ecosystem. The continuous use of irrigation water can affect structure of the soil and indirectly affecting the trees and plants within the habitat. More so, the accumulation of potentially toxic elements in the environment can be detrimental to the aquatic ecosystem, terrestrial system very close to the wet area and man. The identification and quantification of trace metals contamination and mobilization in the environment are essential tools to raise environmental scientific issues (Sutherland, 2000, Tijani et al. 2007). Trace metals are usually derived from both natural (geogenic) and artificial (anthropogenic) sources (Naseem et al. 2010; Tijani et al. 2007). Due to heavy agricultural practices, rapid growth in population and urbanization, exploration and exploitation of natural resources and lack of adherence to environmental regulations, the level of these metals might be affected in the environment over the past decades through various human activities (Widianarko et al. 2000; Tijani et al. 2004, Tijani et al. 2007; Omotoso and Tijani, 2011). Both water and sediments (soils) can be employed as indicators for trace elements (Ajayi, 1990; Sutherland et al. 2000; Tijani et al. 2007). At this juncture, for effective control and management of floodplains for agriculture, domestic and industrial purpose, there is the need for clear understanding of the inputs, sources and the distributions of these metals into the floodplain system.

Agricultural practices should be one of the major concerns of every nation as these affect the health of all. The indiscriminate use of fertilizers, manures, heavy tractors on agricultural land should be skillfully controlled as these could alter the chemistry and increase the concentrations of heavy metals in the soil. The main objective of this study is to evaluate some of the trace/heavy metals concentration in the soil of River Niger Floodplain at Jebba, Nigeria and to determine the possible sources of the heavy metals.

2. LOCATION AND ENVIRONMENTAL SETTING.

The study area lies between Longitudes $4^0 49'$ E and $4^0 51'$ E and Latitudes $9^0 06'$ N and $9^0 11'$ N (Figures 1 and 2). It makes the western part of sheet 181 Jebba SE. It lies within the north central Nigeria. The area of study is fairly accessible by footpath and a highway and may sometimes be limited by thick vegetation, marshy and swampy areas, rivers and streams. The climatic condition of the study area is dry and wet with two distinct seasons, the rainy and dry seasons. The rainy season runs from April to November, while the dry season extends from November to April. The average annual temperature ranges between 35^0 C during the day and 25^0 C at night. The annual range of rainfall in the wet season is about 1500m. The area lies within the Guinea Savannah vegetation belt of Nigeria characterized by scanty trees, shrubs and grasses because of the moderate annual rainfall. The area is densely characterized by agricultural activities.

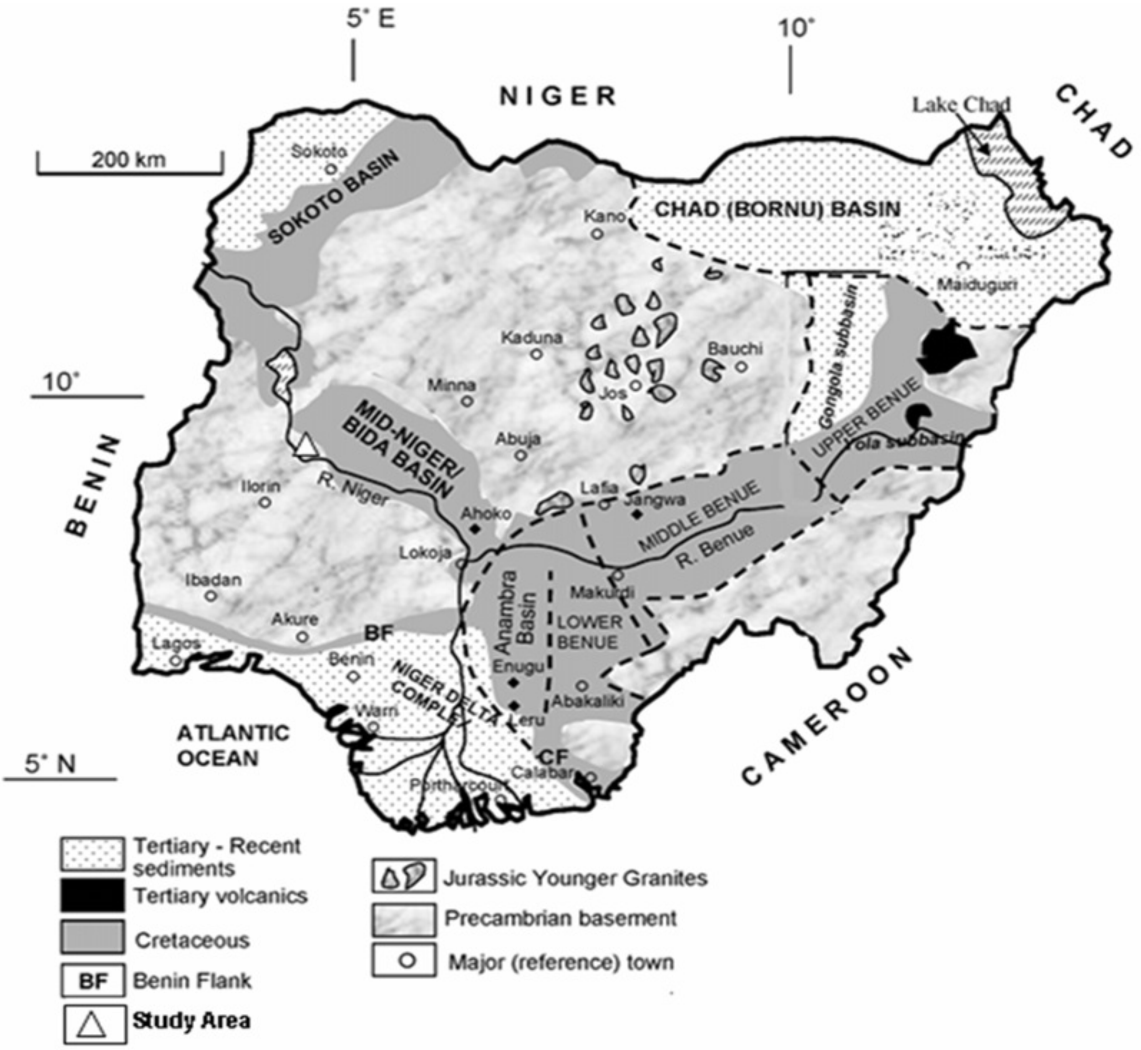

Figure 1: Geological Map of Nigeria (after Obaje, 2004)

The area is situated across the basement complex of Nigeria and Bida basin. The basement rocks comprise of migmatite gneiss, quartzite complex, granitoids and minor acid dykes while the sedimentary terrain consists essentially of sandstones, conglomerates and claystones of Campanian to Maastrichtian age (Okonkwo, 1992; Omotoso and Ojo, 2012).

3. MATERIALS AND METHODS

3.1. Sampling, Sample preparation and Analysis:

Soil samples were collected at several locations from the study area (Figure 2) covering the floodplain and Figure 3 shows a section within the floodplain where samples were taken. The samples were collected by simple scooping of the soil using a clean plastic rubber container and stored in clean polyethylene bags. The collected samples were dried and pulverized in the laboratory prior to geochemical analysis. Pulverization was carried out in the Department of Geology and Mineral Sciences, University of Ilorin, Nigeria. The geochemical analysis was carried out at ACME laboratory, Canada using Inductively Coupled Plasma Mass Spectrometry (ICP/MS) and X-ray Fluorescence (XRF) techniques.

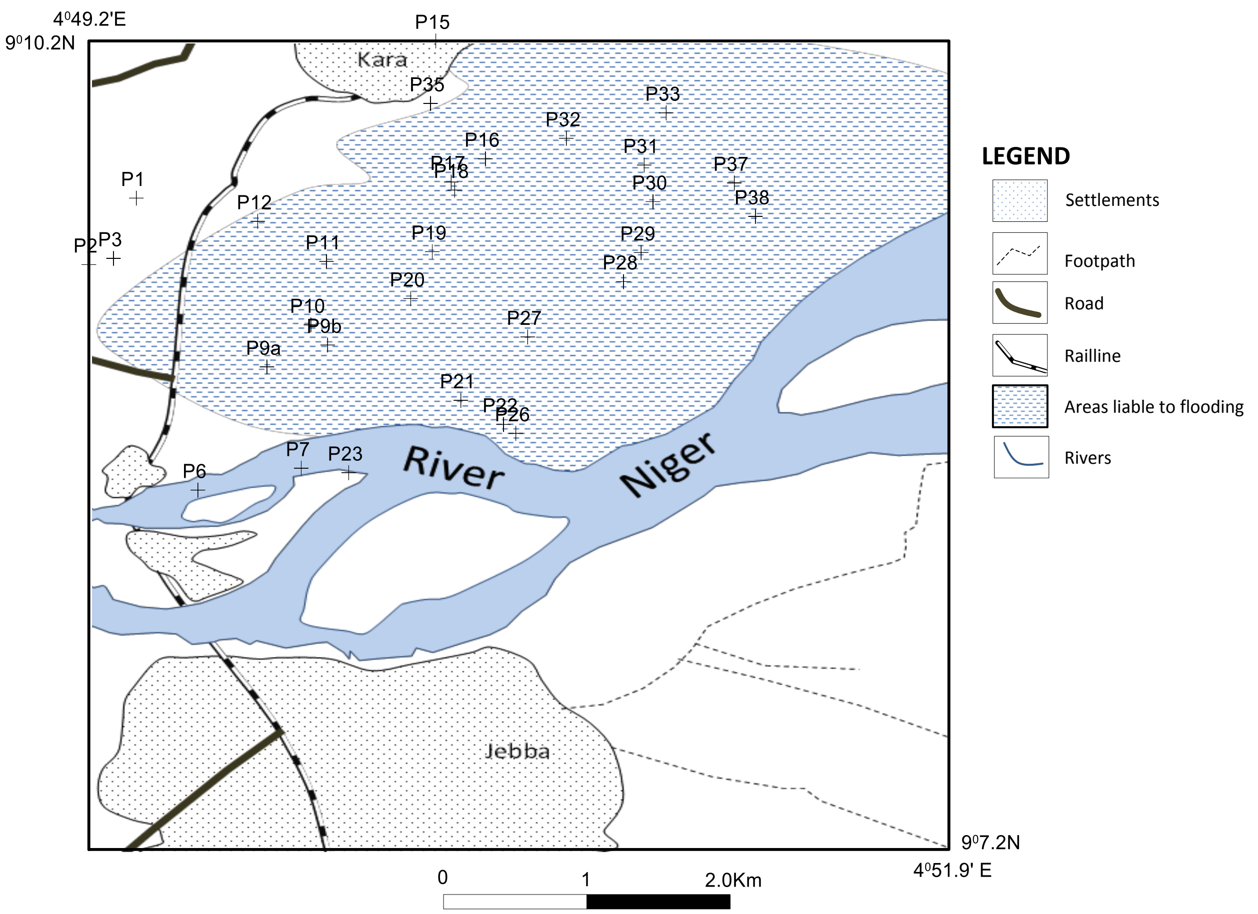

Figure 2: location map of the study area showing sampling points (adapted from NGSA, 2008)

3.2 Assessments of Metal Contamination

For the assessment and quantification of the level of contamination in the soil samples the following quantitative contamination indices were adopted to illustrate the concentration trends and also to allow easy comparison among the measured parameters: anthropogenic factors (AF) or

Contamination factor (C_F), index of geo-accumulation (I_{geo}), enrichment factor (EF) and degree of contamination (C_{deg}).

Figure 3: one of the floodplain locations in the study area.

3.2.1 Contamination Factor (C_F)

This is the single index determined by the relation:

$$C_f = C_m / B_m \quad (1)$$

where C_f= *contamination factor of the element of interest;* B_m=background concentration in this study; C_m= concentration of the element in the sample.

Contamination factor has four categories which include: <1 low contamination factor; 3-6= considerable contamination factor; >6= very high contamination factor (Hakanson, 1980).

3.2.2 Degree of Contamination (C_{deg})

This is the sum of all the contamination factors in the sample. It is indicated as:

$$C_{deg} = \sum (C_m / B_m) \quad (2)$$

where C_m=measured concentration in soil; B_m=local background concentration (value) of metal, m within the pristine area of the catchment.

Four categories have been defined for the degree of contamination which includes: <8=low degree of contamination; 8-16=considerable degree of contamination; >32=very high degree of contamination (Hakanson, 1980).

3.2.3 Enrichment Factor (EF)

The enrichment factor of an element in the studied samples is based on the standardization of a measured element against a reference element. A reference element is often the one characterized by low occurrence variability. It is used to differentiate trace metals originating from human activities and those of natural sources. This is calculated by the following formula:

$$EF= [X_S/E_{S\,(ref)}]/ [X_C/E_{C\,(ref)}] \quad (3)$$

where X_S=concentration of element of interest in sample; $E_{S(ref)}$=concentration of the reference element used for normalization in the crust (Taylor and Maclenan, 1985).

3.2.4 Index of Geo-accumulation (I_{geo})

This is widely used in the assessment of contamination by comparing the level of trace metal obtained to a background levels originally used with bottom sediments (Muller, 1979) which can also be adopted to water and soil contamination (Tijani et al. 2007; Omotoso and Tijani, 2011). It is calculated by:

$$I_{geo} =\log2 [(C_m)/ (1.5*B_m)] \quad (4)$$

where C_m= measured concentration of in soil or water; B_m = local background concentration (value) of metal, m within the pristine area of the catchment. 1.5 is a factor for possible variation in the background concentration due to lithologic differences. The following classification is given for geo-accumulation index (Huu et al., 2010; Muller, 1979) : <0 = practically unpolluted, 0-1 = unpolluted to moderately polluted, 1-2 = moderately polluted, 2-3= moderately to strongly polluted, 3-4 = strongly polluted, 4-5 = strongly to extremely polluted and > = extremely polluted.

3.2.5 Statistical analysis

In order to study the characteristics of the floodplain soil and to determine the degree of association among the heavy metals, person correlation method was adopted using Microsoft Excel package.

4. RESULTS

The heavy metal concentrations and the statistical summary are presented in Table 1; the statistical summary of the contamination factor, degree of contamination, enrichment factor, index of geo-accumulation and correlation coefficient are also presented in Tables 2, 3 and 4. Figures 4 and 5 illustrate the profiles of heavy metals averages and contamination indexes of the soil samples in River Niger Floodplain, Jebba, Nigeria. Cr ranged from 20.53 ppm in location P2 to 123.16ppm in location P6 with an average of 69.1ppm; Mn ranged from 232.35ppm in locations P9 and P10 to 2555.35ppm in location P2 with an average of 503.43ppm; V ranged from 29ppm in location P39 to 134ppm in location P18 with an average of 84.17ppm; Cu varied from 4ppm in location P39 to 42.3ppm in location P6 with an average of 20.66ppm; Zn ranged from 5ppm in location P39 to 70ppm in location P18 with an average from 33.43; Pb ranged from 4.4ppm in location P39 to 25.3ppm in location P18 with an average of 13.86ppm; Ni also ranged from 3.6ppm in location P39 to 27.7ppm in location P18 with an average of 14.4ppm.

Table 1: Concentrations of the heavy metals and their respective statistical summary.

Sampling Points	Cr, ppm	Mn, ppm	V, ppm	Cu, ppm	Pb, ppm	Zn, ppm	Ni, ppm
P1	54.736	464.7	64	13.1	7.5	22	14.9
P 2	20.526	2555.85	70	10	11.6	25	9.8
P 3	68.42	309.8	59	11.8	9.8	13	11.8
P 4	27.368	309.8	46	6	7	17	4.1
P 5	27.368	542.15	53	8.1	8.1	13	7
P 6	75.262	464.7	122	42.3	22.1	62	25.7
P 7	75.262	387.25	89	17.5	11.1	30	15.2
P 9	75.262	232.35	73	15.1	11	17	11.6
P 10	88.946	232.35	84	19.2	13.1	26	16.9
P 11	82.104	464.7	76	25.2	12.7	43	15.8
P 12	75.262	232.35	83	24.7	19	33	16.1
P 16	41.052	542.15	77	16.5	14	32	11.9
P 17	68.42	1161.75	100	29	23.3	58	20.6
P 18	88.946	1084.3	134	34	25.3	70	27.7
P 19	47.894	464.7	73	15.3	10.6	26	14.2
P 20	54.736	309.8	54	10.6	8.5	15	8.5
P 21	95.788	387.25	112	26.2	16.1	39	15.5
P 22	82.104	387.25	105	26.4	15.8	45	16
P 26	123.156	464.7	122	35.4	17.8	58	23.9
P 27	82.104	232.35	100	29.1	16.2	43	14.7
P 28	68.42	619.6	79	16.7	10.4	32	17.5
P 29	95.788	309.8	107	23.4	15.8	33	14.2
P 30	102.63	542.15	123	31.3	18.2	56	19.2
P 31	54.736	232.35	40	8.5	5.6	14	5.9
P 32	82.104	464.7	133	40.8	19.3	62	24.5
P 33	68.42	542.15	109	27.4	21.9	39	14.9
P 35	68.42	387.25	55	20.5	17.5	28	9.9
P 37	54.736	232.35	63	13.3	9.2	14	7.5
P 38	82.104	309.8	91	18.5	12.9	33	13
P 39	41.052	232.35	29	4	4.4	5	3.6
Average, ppm	69.1	503.43	84.17	20.66	13.86	33.43	14.4
Minimum, ppm	20.53	232.35	29	4	4.4	5	3.6
Maximum, ppm	123.16	2555.85	134	42.3	25.3	70	27.7
Standard deviation	23.45	445.96	28.42	10.15	5.46	17.32	6.1
Median, ppm	71.84	387.25	81	18.85	13	32	14.8
Variance	549.97	198881.38	807.73	103.06	29.86	300.05	37.26

Table 2: Statistically summary of the contamination indexes of the heavy metals in the soil

		AF/CF			I-GEO			EF		
metal	mean	min	Max	mean	Min	max	mean	min	max	backgroun
Mn	2.2	1.02	11.18	0.3	-0.56	2.9	1.1	0.39	4.48	228.6
Cr	0.8	0.25	1.48	-1	-2.61	-0.02	0.5	0.1	0.78	83.4
V	0.6	0.22	1.03	-1.3	-2.75	-0.54	0.2	0.1	0.36	130
Cu	1.7	0.32	3.41	0	-2.22	1.19	0.6	0.22	0.96	12.4
Pb	0.2	0.06	0.37	-3	-4.53	-2.01	0.1	0.03	0.15	67.9
Zn	0.5	0.07	0.99	-1.9	-4.41	-0.6	0.2	0.04	0.28	70.7
Ni	1.3	0.32	2.43	-0.4	-2.25	0.7	0.4	0.23	0.64	11.4

Table 3: Degree of contamination and its interpretations

Sample ID	Cdeg	Interpretation of C(deg)
1	6	LDC
2	14.2	MDC
3	4.9	LDC
4	3.2	LDC
5	4.7	LDC
6	10.7	MDC
7	6.6	LDC
9	5.1	LDC
10	6.3	LDC
11	7.8	LDC
12	6.7	LDC
16	6.5	LDC
17	12	MDC
18	13.4	MDC
19	6.2	LDC
20	4.4	LDC
21	8	MDC
22	7.9	LDC
26	10.5	MDC
27	7.3	LDC
28	7.6	LDC
29	7.2	LDC
30	9.8	MDC
31	3.5	LDC
32	10.6	MDC
33	8.4	MDC
35	6.1	LDC
37	4.2	LDC
38	6.3	LDC
39	2.5	LDC

LDC: low degree of contamination; MDC: moderate degree of contamination.

Table 4: Correlation matrix of the heavy metals

	Cr, ppm	Mn	V	Cu	Pb	Zn	Ni
Cr, ppm	1						
Mn	-0.3	1					
V	0.74	0.13	1				
Cu	0.74	0.02	0.92	1			
Pb	0.58	0.22	0.85	0.89	1		
Zn	0.64	0.22	0.91	0.94	0.88	1	
Ni	0.69	0.15	0.89	0.9	0.81	0.92	1

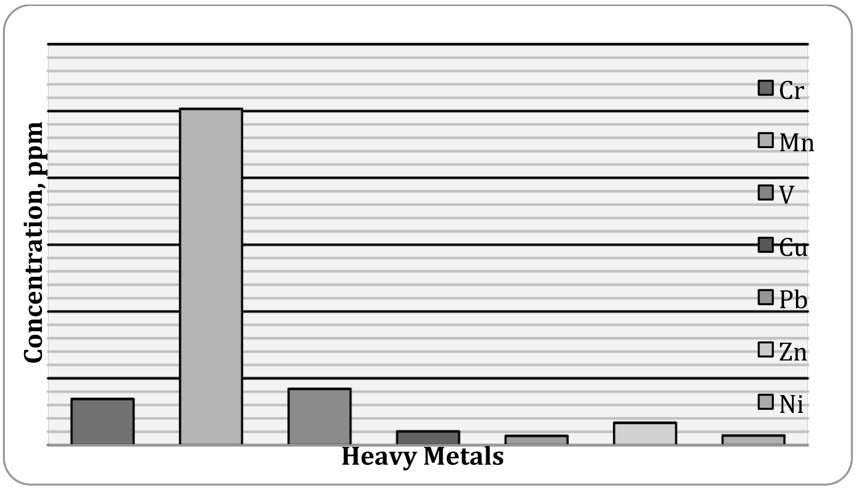

Figure 4: Profile of heavy metals averages in River Niger Floodplain, Jebba.

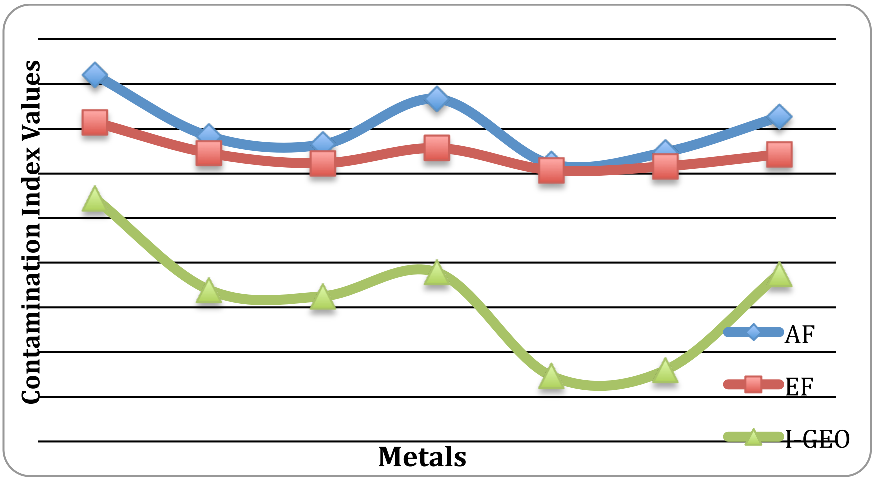

Figure 5: contamination indexes of the soil samples

5. DISCUSSION

5.1 Heavy metal concentrations in soils

The average values (Figure 4) obtained for Cr, Mn, Cu and Ni (69.1, 503.43, 20.66 and 14.4ppm) are comparable to the average values obtained by Tijani et al., 2007 (62.85, 454.4, 29.9 and 22.8mg/kg respectively) in their paper titled: "a geochemical assessment of water and bottom sediments contamination of Eleyele lake catchment, Ibadan, southwestern Nigeria."

5.1.1 Assessment of Heavy Metal Contaminations

The assessment of heavy metal contamination was estimated in this study using the quantitative indices earlier mentioned. The average crustal averages were used as background values for the soil samples in order to give a comparative idea about the quality and degree of heavy metal contamination of the River Niger Floodplain at Jebba.

5.1.2 Contamination Factor (C_f) or Anthropogenic Factor (AF):

The contamination factor or anthropogenic factor for each element was computed and the result presented in Table 2. The average contamination factors or average anthropogenic factors (AF) of Mn, Cu and Ni are estimated to be 2.2, 1.7 and 1.3 respectively which indicate moderate contamination factor and that of Cr, V, Pb and Zn are 0.8, 0.6, 0.2 and 0.5 respectively showing low contamination factor (Rastmanesh et al. 2010; Atiemo et al. 2011). The source of the enrichment in Mn, Cu and Ni is likely to be from various agricultural practices in the area (irrigation, use of fertilizers, organic manure and human activities) as well as emission of Cu from tyre and brake abrasions of tractors (Thorpe and Harrison, 2008; Atiemo et al. 2011; Tijani et al. 2007).

5.1.3 Degree of Contamination:

The degree of contamination (Cdeg), computed for each location together with the interpretations is presented in Table 3. 70% of the samples give low degree of contamination (LDC) while 30% give moderate degree of contamination (MDC). Although, the degree of contamination in the soil samples is not very high, there should be thorough monitoring of the level of these heavy metals in the soil of the floodplain so as to prevent relative health hazards to man and the livestock in the area.

5.1.4 Geo-accumulation Index

Results from geo-accumulation index (Igeo) revealed that Igeo value for Mn is 0.3 which indicates unpolluted to moderately polluted whereas, Cr, V, Cu, Pb, Zn and Ni have values less than zero indicating practically unpolluted (Rastmanesh et al. 2010; Atiemo et al. 2011). However, the estimated index of geo-accumulation revealed Igeo<1 for all the heavy metals Indicating no contamination with respect to these metals (Tijani et al. 2007).

5.1.5 Enrichment Factor (E_f)

The summary of the enrichment factors in the heavy metals of the soil samples is presented in Table 3. The values of the heavy metals fall within the range of deficiency to minimal enrichment. The EF values obtained for Cu, Pb, Mn, Ni and Zn are similar to those Mmolawa et al, 2011 obtained for the same metals in their study area.

5.1.6 Statistical Analysis

Table 4 presents the correlation matrix of the heavy metals showing their level of association from specific sources. For example, Pb/Zn (0.88); Pb/Ni (0.81); Cu/Pb (0.89); Cu/Zn (0.94); Cu/Ni (0.90) have strong correlation with each other depicting same source. In other words, strong correlations signify that each paired metals have common contamination sources (Mmolawa et al. 2011). However, weak correlation (range=0.02-0.22) is found between Mn and the other heavy metals which shows that they have very weak degree of association.

6. CONCLUSION

Anthropogenically and geogenically impacted River Niger Floodplain soils at Jebba were assessed using contamination factor, degree of contamination, enrichment factor and geo-accumulation index for Mn, Cr, V, Pb, Zn, Ni and Cu.

Enrichment factor shows that all the metals are deficient to minimally enriched. The contamination factor shows that Mn, Cu and Ni have moderate contamination factor while Cr, V, Pb and Zn show low contamination factor in the soil samples. 70% of the samples show low degree of contamination while 30% indicates moderate degree of contamination. The geo-accumulation index shows that Mn fall within unpolluted to moderately polluted and Cr, V, Cu, Pb, Zn and Ni indicate practically unpolluted. Anthropogenic factor suggests that Mn, Cu, and Ni are being controlled by various anthropogenic (agricultural activities, human activities, vehicular emission etc.) and geogenic activities in the catchment area while Cr, V, Pb and Zn are being enriched mainly by geogenic activities.

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