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ENVIRONMENTAL IMPACT ASSESSMENT AND BASELINE STUDIES OF OLUYOLE INDUSTRIAL ESTATE EFFLUENTS, IBADAN SOUTHWESTERN NIGERIA

O. C. Adeigbe

Department of Geology, University of Ibadan, Ibadan. Nigeria

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Abstract

Oluyole Industrial Estate, the most industrialized centre in Ibadan city is underlain by migmatised biotite hornblende gneiss, Quartzite and Gneiss Schist. The continuous increase in human activities and lack of environmental best practices due to increase in population and attendant urbanization challenges have led to increasing level of toxic and non-toxic metals in the area. This present study aimed at determining the impact of waste disposal and effluent discharge on water, soil and sediment in the area. Forty five samples covering the three media were collected which were further subjected to granulometric, geochemical analyses using Inductively Coupled Plasma Atomic Mass spectroscopy (ICP-MS).Also the Physico-chemical parameters of the water samples were determined.

The grain size analysis revealed the sediment and the soil samples to be poorly sorted, the mean sizes ranges from moderate to fine sand, the skewness of the soil sample ranged from negatively skewed to very positively skewed, while that of the sediments ranged from very negatively skewed to nearly symmetrical. The Kurtosis of the soil and sediment samples was platykurtic and platykurtic to leptokurtic respectively. The geo-accumulation index of the sediments and soil revealed that the concentration of heavy metals ranged from practically uncontaminated to heavily contaminated and from practically contaminated to moderately contaminated. The observed positive correlation coefficient among some of the elements and grouping using the R-mode factor analysis revealed Zn-Cu (0.90), Cr-Ni (0.94), Zn-Pb (0.91) thus indicating common sources for these metals in the soil and stream sediments of the area. The physico-chemical parameters of the water reveals slightly acidic to slightly basic while other parameters such as total hardness and Total dissolve Solid (TDS) fall within WHO maximum permissible level. The EC ranged from 226-589, while the mean concentration of the cations is in the order Ca >Na > K > Mg and anions is HCO_3 > Cl > SO_4 > NO_3 revealing ions expected in fresh surface water. The Trilinear Piper diagram characterise the water as alkaline earth water type which is predominantly rich in HCO_3 while the Gibbs and Schoeller diagrams revealed the water samples to be a function of dilution effects and high concentration of HCO_3, Ca^{2+} ion and decrease in SO_4^{2-} ion respectively. Conclusively, it can be said that the surface water within the study area is suitable for use since all parameters fall within the maximum permissible limit of the WHO standard. The study also deduced that human activities are major contribution of heavy metal distribution and subsequent enrichment in the study area as revealed by geochemical and geo-accumulation index map.

Keywords: Oluyole industrial estate; Hydrogeochemical; Geoaccumulation Index; Urbanization; Heavy metals.

1. Introduction

Oluyole industrial estate is delimited by longitude and latitude is $3^0 45^1$N and $3^0 52^1$N and $7^0 18^1$E and $7^0 26^1$ E (Fig. 1). Because of the proximity to the downtown areas and market centre, it has developed rapidly over time to become the most industrialised Centre in Ibadan. It boast of industries such as Procter and Gamble, Sumal Nigeria, Zartech Fina, Seven up Bottling Company, Machines and Mercantile industries, Interpark Nigeria limited., Armard Technology and Nigerite Depo. Geologically, the study area is underlain by Migmatised biotite hornblende gneiss, Quartzite, Gneiss-Schist complex (Fig.2) [1-3]. Globally however, environmental pollution is a major and global problem posing serious risk to man when permissible concentration levels are exceeded. Also, scientific breakthrough in modern technology and the rapid industrialization are among the foremost factors for environmental pollution, though industrialization is vital to a nation's social-economic development as well its political structure, however, its impart if not well monitor and controlled could pose danger through technology employed by industries, size, nature of products, and complexity of waste discharged.

Soils and sediments are usually considered as a sink for trace metals though sediment is preferred as monitoring tools because they show less variation in time and space and since contaminant concentrations are in orders of magnitude than those in water [4-6]. There are two main source for discharging heavy metals into the environment; anthropogenic source which are due to human activities such as industry, agriculture, mining activities which are transported by rivers and lithogenic source which is the natural process such as weathering and denudation processes affecting rocks.

This study aimed at evaluating the environmental assessment of Oluyole Industrial Estate effluents and to have baseline information of the area for future reference through sedimentological and geochemical study.

2. Materials and Methods

Forty five samples were collected covering soil, sediment and surface water (three samples per location). Sampling locations were chosen to provide an unbiased representation of the samples collected, thus sampling was done across the river courses that drains the industrial estate (Fig. 3). In the course of sampling, the pysico-chemical properties of the water samples were measured using appropriate probe to measure the pH, EC, TDS. After sampling, sediment and soil samples were air dried .The soil were then disaggregated in a mortar with a pestle. The soil and sediment samples were subjected to granulometric study which included sieving to obtain the 75μm fraction for subsequent analysis for heavy metals concentration using Inductively Coupled Plasma Atomic Mass spectroscopy (ICP-MS) at Acme laboratory in Canada. The water chemistry to determine the major Anions and Cations were carried out at Petroc laboratory in Ibadan, Nigeria. The granulometric studies of the sediment and soil samples were done at the Dept of Geology, University of Ibadan, Nigeria. The various results obtained were subjected to statistical analyses using Excels, SPSS 15, Window Arc GIS and Arc view to determine the interrelationships among the chemical elements.

3. RESULTS AND DISCUSSION

3.1. Granulometric study

The grain size analyses of both the soils and sediments samples revealed mean values of 1.30 to 2.10 and 1.63 to 2.40 respectively indicating a medium to fined grained sand while the degree of sorting for the soils and sediments also ranges from 1.01 to 1.58 and 1.10 to 1.43, which implies that both media are poorly sorted. The skewness values for the soils and sediments ranges from -0.17 to 0.97 and -0.32 to 0.97 indicating a negatively to very positively skewed. The kurtosis values ranges from 0.55 to 0.89 for soils which reveal a very kurtic to very leptokurtic. On the other hand, the kurtosis value for the sediments ranges from 0.78 to 1.45 indicating a platykurtic to very leptokurtic (Tables 1 and 2).

3.2. Hydro-chemistry

The results of the analyses of water samples are summarised in (Table 3). The pH and temperature ranged from 6.271 to 7.686 and 28.2^{0}C to 29.7^{0}C respectively indicating a slightly acidic to slightly basic and it fall within WHO [7] standard for the maximum permissible level of pH temperature for potable water. Total hardness values ranged from 108 -184mg/l suggesting a moderately hard to hard. All the values for the total hardness obtained fall within the maximum permissible level (500mg/l) recommended level by WHO [7]. The total dissolved solid (TDS) ranged from 170 - 441 mg/l falling within the prescribed standard depicting non - pollution. The mean concentration of the cations is in the order Ca >Na > K > Mg while that of anions is $HCO_3 > Cl > SO_4 > NO_3$. Statistical analysis coefficient of correlation indicated positive correlation between some pairs of parameters (Table 4). Strong correlation exists among the cations and the anions which is also applicable to the TDS and EC (Fig. 4) indicating contribution of ionic component to the overall TDS.

Table 1. Calculated granulometric parameters for soil samples

S/N	MEAN		SORTING		SKEWNESS		KURTOSIS	
	Results	Interpretation	Results	interpretation	Results	Interpretation	Results	Interpretation
1	2.03	Fine sand	1.31	Poorly sorted	0.80	Positively skewed	0.79	Platykurtic
2	1.53	Medium sand	1.20	Poorly sorted	0.24	Positively skewed	0.89	Platykurtic
3	1.56	Medium sand	1.19	Poorly sorted	0.24	Positively skewed	0.87	Platykurtic
4	1.93	Medium sand	1.31	Poorly sorted	0.49	Positively skewed	0.86	Platykurtic
5	1.43	Medium sand	1.01	Poorly sorted	0.25	Positively skewed	0.81	Platykurtic
6	1.40	Medium sand	1.08	Poorly sorted	0.24	Positively skewed	0.81	Platykurtic
7	1.42	Medium sand	1.05	Poorly sorted	0.39	Very Positively skewed	0.80	Platykurtic
8	2.10	Fine sand	1.41	Poorly sorted	-0.07	Negatively skewed	0.55	Very Platykurtic
9	1.90	Medium sand	1.58	Poorly sorted	1.80	Very Positively skewed	0.72	Platykurtic
10	1.30	Medium sand	1.15	Poorly sorted	0.40	Very Positively skewed	0.79	Platykurtic
11	1.56	Medium sand	1.23	Poorly sorted	0.22	Positively skewed	0.79	Platykurtic
12	1.70	Medium sand	1.22	Poorly sorted	0.97	Very Positively skewed	0.71	Platykurtic
13	1.60	Medium sand	1.09	Poorly sorted	0.76	Very Positively skewed	0.81	Platykurtic
14	1.76	Medium sand	1.20	Poorly sorted	0.04	Nearly symmetrical	0.72	Platykurtic
15	1.73	Medium sand	1.22	Poorly sorted	0.14	Positively skewed	0.73	Platykurtic

Table 2. Calculated granulometric parameters for sediments samples

S/N	MEAN		SORTING		SKEWNESS		KURTOSIS	
	Results	Interpretation	Results	Interpretation	Results	Interpretation	Results	Interpretation
1	2.40	Fine sand	1.28	Poorly sorted	-0.30	Very negatively skewed	0.78	Platykurtic
2	1.73	Medium sand	1.31	Poorly sorted	0.04	Nearly symmetrical	0.88	Platykurtic
3	2.10	Fine sand	1.35	Poorly sorted	0.19	Positively skewed	1.41	Leptokurtic
4	2.36	Fine sand	1.14	Poorly sorted	-0.89	Very negatively skewed	1.05	Mesokurtic
5	2.36	Fine Sand	1.43	Poorly sorted	-0.36	Negatively skewed	0.71	Platykurtic
6	1.63	Medium Sand	1.30	Poorly sorted	-0.05	Negatively skewed	0.86	Platykurtic
7	2.23	Fine Sand	1.26	Poorly sorted	-0.23	Very negatively skewed	0.88	Platykurtic
8	2.03	Fine sand	1.25	Poorly sorted	-0.03	Negatively skewed	0.64	Platykurtic
9	2.16	Fine sand	1.27	Poorly sorted	-0.21	Very negatively skewed	0.98	Mesokutic
10	2.06	Fine sand	1.26	Poorly sorted	-0.16	Negatively skewed	0.79	Platykurtic
11	1.93	Medium sand	1.31	Poorly sorted	-0.40	Very negatively skewed	1.06	Leptokurtic
12	2.13	Fine sand	1.25	Poorly sorted	-0.22	negatively skewed	0.81	Mesokurtic
13	1.73	Medium sand	1.21	Poorly sorted	-0.03	Nearly symmetrical	1.45	Leptokurtic
14	1.73	Medium sand	1.10	Poorly sorted	0.02	Nearly symmetrical	1.43	Mesokurtic
15	1.90	Medium sand	1.15	Poorly sorted	-0.32	Very negatively skewed	0.91	Mesokurtic

Table 3. Summary of the physico–chemical parameter of the water samples from the study area

Parameters	Minimum	Maximum	Mean	Std dev.	Median	WHO (Standard) RL-MPL
PH	6.27	7.69	7.14	0.36	-	6.5-9.5
EC	226.00	589.00	423.00	103.55	-	400-1480
TDS	170.00	441.00	317.40	77.52	-	500-1000
Total Hardness	108.00	184.00	156.47	24.92	-	100-500
Total Alkalinity	98.00	175.00	143.93	28.53	-	-
Cl^-	17.19	55.44	32.46	12.66	25.82	250-600
NO_3^-	0.00	5.45	1.26	1.43	3.31	25-50
HCO_3^-	112.00	214.00	173.40	35.08	184	-
SO_4^-	9.00	37.00	24.60	7.15	24	250-400
Ca^{2+}	32.20	62.30	49.39	8.70	52.3	75-200
Mg^{2+}	5.10	10.10	7.53	1.40	7.9	50-150
Na^+	14.30	33.20	23.49	5.33	22.2	30-212
K^+	1.60	15.70	7.64	3.80	6.6	30-212

RL= Rear Level *MRL=Maximum Permissible Level*

Table 4. Result of Pearson Correlation Analysis of the Water Samples in the Study Area

	pH	EC	TDS	Total Hardness	Total Alkalinity	Cl^-	$N0_3^-$	$HC0_3^-$	$S0_4^{2-}$	Ca^{2+}	Mg^{2+}	Na	K
PH	1.00												
EC	-0.17	1.00											
TDS	-0.17	**1.00**	1.00				,						
Total Hardness	-0.13	**0.91**	**0.91**	1.00									
Total Alkalinity	0.29	**0.71**	**0.71**	**0.78**	1.00								
Cl^-	-0.28	**0.74**	**0.74**	0.48	0.21	1.00							
NO_3^-	-0.81	-0.08	-0.08	-0.07	-0.57	0.15	1.00						
HCO_3^-	0.27	**0.72**	**0.72**	**0.79**	**1.00**	0.21	-0.54	1.00					
SO_4^{2-}	-0.22	**0.79**	**0.79**	**0.74**	**0.57**	**0.45**	0.04	**0.58**	1.00				
Ca^{2+}	-0.07	**0.91**	**0.91**	**0.97**	**0.77**	**0.52**	-0.08	**0.78**	**0.75**	1.00			
Mg^{2+}	0.07	**0.83**	**0.83**	**0.84**	**0.83**	0.38	-0.26	**0.83**	**0.77**	**0.88**	1.00		
Na^+	0.08	**0.55**	**0.55**	0.37	0.45	**0.68**	-0.17	0.43	0.36	0.47	0.49	1.00	
K^+	0.24	0.36	0.36	0.13	0.11	**0.66**	-0.07	0.14	0.06	0.19	0.13	**0.51**	1.00

The result of the regression analysis between TDS and EC revealed high to near perfect correlation. $Ca^{2+}$and Mg^{2+} show a very strong relationship with HCO_3 (0.78, 0.83), alkalinity and HCO_3^- also show a very strong relationship (Fig. 5). SO_4^{2+} has a strong correlation with $Ca^{2+}$and Mg^{2+} (0.75, 0.77) respectively. This is an indication of possible introduction of HCO_3^- from dissolution from the waste dump while SO_4^{2+} may have resulted probably from waste materials from industrial effluents. Other cations and anions also show positive correlation, and this includes: Ca^{2+} and Cl^- (0.52), Na^+ and Cl^- (0.88), K^+ and Cl^- (0.66) K^+ and Na^+ (0.51) respectively. These suggests same provenance for the pairs. On the other hand, a very weak correlation was observed between NO_3^- and Cl^- suggesting an anthropogenic source. The Trilinear plots (Piper diagram) revealed the presence of two water types within the study area; Ca-(Mg)-Na-$HCO_3$and Na-(k)-SO_4 –Cl, while the chemical characteristics of the water tends to alkaline earth water plot with higher alkaline proportion rich in HCO_3^- (80-100%) which possibly resulted from rock-water interaction (Fig. 6) and low SO_4^{2-} ion (20-40%). These cations may have probably resulted from the discharge of petroleum products from the mechanic workshop and or soap factory within the industrial estate. Ca^{2+} ion also resulted from the same source as HCO_3^- ion. The plot of Schoeller diagram [8] also revealed high concentration of HCO_3^-, and Ca^{2+} ions comparing with SO_4^{2-} ion (Fig. 7). From the plot of logTDS values against the ratio of (Na^+/Na^++Ca^{2+}) on the Gibbs diagram [9], the water plotted within the dilution segment of the plots (Fig. 8) which is an indication of the function of dilution effects on the surface water chemistry within the study area.

Based on the result of water from the study area, it revealed that the water falls within the maximum permissible limit of WHO standard [7] for water quality.

3.3. Heavy Metals Chemistry and Geo-accumulation Index

The elemental concentration in the stream sediment samples (Mo, Cu, Pb, Zn, Ni, Co, Mn, As, Cd, Cr) are 0.72, 39.79, 48.48, 109.00, 104.30, 30.40, 1354.00, 0.90, 0.19, 151.30 while in the soil samples it has concentration of 0.5, 9.7, 15.0, 36.2, 9.6, 9.9, 400,0.4, 0.0, 35.9. for each respective metals**.** These were also shown in a distribution maps. Environmental geochemical phenomena including heavy metal concentration in stream sediments when correlated are believed to be caused by physico-chemical features of elements and geochemical processes.

The distribution of Cu ranges from 7.84 to 39.79 ppm with an average value of 16.1, Pb ranged from 9.00 to 48.48ppm with an average value of 24.3, while that of Zn ranges from 21.10-109.00ppm with an average of 58.82, all in the soil samples, while in the stream sediment samples Cu ranged between 9.7 to 74.5ppm with an average concentration of 28, Pb ranged from 15.0-1494.0ppm with an average value of 142.7,while Zn also ranged from 36.2 to 231.4ppm with an average value of 100.1**.** Figs 9, 10, and 11 shows the distribution map of Cu, Zn and Pb in the soil and sediment samples respectively. The heavy metals are focused due to potential hazard to the environments. The Principal Component Analysis (PCA) is used to access the metal behaviour in sediment [11-12]. The essence is to detect the hidden structures and association of elements in the data set .The first three PCA for soil accounts for 41.009% of the total variance, the variance F_1, F_2 and F_3 are 41.01%, 36.89% and 12.012% respectively (Table 5).

Table 5. Total variance in PCA for soil

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.101	41.009	41.009	4.101	41.009	41.009
2	3.689	36.893	77.902	3.689	36.893	77.902
3	1.202	12.016	89.918	1.202	12.016	89.918
4	0.409	4.091	94.010			
5	0.260	2.599	96.609			
6	0.182	1.816	98.425			
7	0.097	0.974	99.399			
8	0.038	0.382	99.782			
9	0.017	0.173	99.955			
10	0.005	0.045	100.000			

Apparently the result of the PCA corresponds with the correlation coefficient factor 1(CCF 1) has strong loadings of Ni, Co, Mn, and Cr. CCF among these group of elements exceed 0.50. Ni and Cr belong to the siderophile element, these are the main rock forming elements. This elemental association is considered to represent the lithology of the study area, and a natural input, both derived from the same source .i.e. from transported terrigenous detritus materials. Factor 2 (CCF 2) loading on Mo, Cu, Zn, As, Cd exceeds 0.50 (Table 6).

Table 6. Principal component analysis for soils

	Component		
	1	2	3
Mo	0.041	0.799	-0.490
Cu	0.471	0.805	0.203
Pb	-0.572	0.715	0.263
Zn	-0.421	0.809	0.368
Ni	0.831	0.437	0.028
Co	0.935	0.133	0.094
Mn	0.916	-0.037	0.264
As	-0.298	0.586	-0.692
Cd	-0.536	0.642	0.353
Cr	0.771	0.522	-0.182

All other elements excluding Mo have a quite similar geochemical character and as such occur in close association with each other, the source of the four elements is possibly anthropogenic. Mo which does not occur in association with the other four elements may possibly have different source, probably geogenic. Factor 3, (CCF 3) within the group of elements is not significant, because the entire factor loading of the entire element in this group fall below 0.50. The first four PCA for the stream sediments accounts for 88.40% of total variance and the variance F1, F2, F3 and F4 are 40.48, 25.97, 12.51 and 9.44% respectively. Apparently the results of PCA correspond well with the CCF. Factor 1 has strong loadings of Cu, Pb, Zn, As and Sb. CCF exceeds 0.60. Pb has a higher correlation with Zn; Zn has a quite similar geochemical character with Pb (Table 7). Factor 2 loadings on Mo, Ni, Cr exceeds 0.65, they belong to the siderophile elements, they are the main rock forming elements, this elemental association is considered to represent the lithology of the study area, and a natural input .i.e. they are derived from transported terrigenous detritus materials. Factor 3 loadings on Cd, exceed 0.50, this suggests anthropogenic source, probably from mechanic workshops. Factor 4, correlation coefficient among this group of elements is not significant (Table 8).

Table 7. Total variance in PCA of Stream sediments

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.45	40.48	40.48	4.45	40.48	40.48
2	2.86	25.97	66.45	2.86	25.97	66.45
3	1.38	12.51	78.96	1.38	12.51	78.96
4	1.04	9.44	88.40	1.04	9.44	88.40
5	0.60	5.43	93.84			
6	0.28	2.57	96.41			
7	0.19	1.68	98.09			
8	0.13	1.22	99.32			
9	0.06	0.56	99.87			
10	0.01	0.12	99.99			
11	0.00	0.01	100.00			

Table 8. Principal component analysis for stream sediments

	Component			
	1	2	3	4
Mo	0.33	0.68	-0.42	0.31
Cu	0.84	0.39	-0.09	-0.12
Pb	0.66	-0.51	0.44	0.29
Zn	0.87	0.38	-0.08	-0.06
Ni	-0.06	0.85	0.40	-0.13
Co	-0.77	0.29	0.37	0.23
Mn	-0.73	0.06	0.40	0.17
As	0.76	0.34	0.14	0.45
Cd	0.35	0.45	0.59	-0.52
Sb	0.66	-0.53	0.42	0.28
Cr	-0.44	0.65	0.02	0.43

Enrichment Factor (EF) as proposed by Simex and Heltz [13] was employed to assess the degree of contamination and to understand the distribution of metals of anthropogenic origin by individual element. Elements which are geogenic have an EF value of nearly unit, while elements of anthropogenic origin have EF of several orders of magnitude. EFs are used to assess the enrichment or depletion of heavy metals. This ratio was calculated with respect to the conservative element in the study area according to Hassan and Ismail [14]; Wang and Qin [15]

$$EF = (M/R)soil/(M/R)background \qquad (1)$$

where M_{soil} is the concentration of element in the sample; R_{soil} is the concentration of conservative element (Ti) in the sample while $M_{background}$ is the background value of the element and $R_{background}$ is the background concentration of conservative element (Ti) in the sample [16] (Table 9).

Also the Index of geo-accumulation (Igeo) proposed by Muller [17] quantifies the degree of metal contamination in terrestrial and aquatic environment and it is expressed as;

$$Igeo = \log_2 \{Cm\}/ (1.5*B_m)\} \qquad (2)$$

where Cm is the measured concentration in soil, sediments or water; B_m is the background concentration (value) of the metal while 1.5 is a factor for possible variation in the background concentration due to lithologic difference.

Table 9. Summary of calculated Enrichment Factors in the soil and sediments

Element	Range (Soil)	Range (Sediments)
Mo	0-1	0-1
Cu	0-1	0-1
Pb	0-5	1-90
Zn	0-3	0-2
Ni	0-1	0
Mn	1	0-2
As	0-1	0
Cd	0-1	0-1
Cr	0-1	0-1

<1=Background concentration, 1-2= Depletion to normal enrichment, 2-5= Moderate enrichment, 5-20= Significant enrichment, 20-40= Very high enrichment and >40= extremely high enrichment ***[17]***

Table 10. Summary of the calculated geo-accumulation indices in the environmental media

Elements (ppm)	Sediments				Soil			
	Using average Shale composition		Using calculated background		Using average Shale composition		Using calculated background	
	Range		Range		Range		Range	
Mo	-3	0	-1	-1	-2	0	-1	0
Cu	-2	1	2	3	-2	1	2	3
Pb	-1	7	2	3	0	7	3	5
Zn	-1	2	0	0	-1	2	3	4
Ni	-4	0	2	3	-3	-2	2	2
Co	-1	1	2	3	-1	1	2	2
Mn	-1	1	5	6	-1	1	5	6
As	-6	0	-2	-1	-2	0	-1	0
U	-2	0	0	0	-2	0	0	0
Cd	-3	1	-3	-2	-3	0	-3	-2
Sb	-3	6	-2	-1	-2	6	-2	1
V	-2	1	3	3	-2	-1	3	3
Cr	-1	0	3	4	-1	0	3	4

Igeo < 0= practically uncontaminated, 0<Igeo<1 = uncontaminated to moderately contaminated, 1<Igeo<2 =moderately contaminated, 2<Igeo<3= moderately to heavy contaminated, 3<Igeo<4= Heavily to extremely contaminated, 5<Igeo= Exremely contaminated.

It can be inferred that the level of contamination for some of these elements namely Cu, Pb, Zn are probably due to automobile emission, auto mobile/painting workshops with lubricant oil.

3.4. Pollution Load Index

The pollution load index (PLI) proposed by Tomlinson *et al.* [17] is also used for this work and it is refers to as the load index and it is obtained as Contamination Factors (CF). The CF is the quotient obtained by dividing the concentration of each metal by background value for each metal.

PLI of a place are calculated by obtaining the n-root from the Contamination Factors obtained from all the metals. Pollution load index for each site was also evaluated as indicated by Tomlinson *et al.* [17]

$$PLI = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \ldots CF_n} \qquad (3)$$

where n is the number of metals and CF is the contamination factor

Contamination factor (CF) =Metal concentration in sediments / background values of the metal.

When the PLI value is >1, it means the area is polluted and when it is <1, it indicates no pollution. Having calculated the Contamination Factor using the above formula for the elements in the soils and sediments samples, PLI for the elements are 0.53 and 0.25 respectively i.e. less than 1 which indicates no pollution. It can be said that the study area since PLI values <1 indicate no pollution, from the values calculated above the study area can thus be said to be not significantly polluted. To ascertain the various contributors to the elemental contents of the media, the results were further evaluated and the results (Figs 13 a & b) showed the various contributors to the level of metals in the sediments from within Oluyole industrial estate. Elements such as Pb, Zn, Co, Mn in soils of study area have been principally contributed by lithogenic sources, while for stream sediments**,** metals such as Mo, Cu, Ni, Ar, Cd and Cr have been contributed more by anthropogenic means.

Table 11. Summary of contamination factor indices for selected metals in soil and sediments

Elements	Contamination factor (Sediment)	Contamination factor (Soil)
Mo	0.432	0.3084
Cu	0.575	0.3233
Pb	7.136	1.7369
Zn	1.112	0.7842
Ni	0.183	0.2057
Co	1.037	0.762
Mn	1.014	0.6892
As	0.092	0.28
Cd	0.4755	0.3177
V	2.8466	0.2204
Cr	0.6795	0.36

4. Conclusions

The main aim of the study was to determine the concentration and the level of the contaminants present in the three sample media within the industrial estate, having concluded the study, it was discovered that the concentration of the heavy metals ,with that of the cations and anions did not reflect to a great extent the level of expected contamination from an industrial environments, instead it revealed that the other level of pollution were through a combination of other anthropogenic factors such as vehicular traffic movement which contributed to the high level of contaminant of heavy metal discovered within the industrial estate other than industrial effluents that is within the permisible level.

The geochemistry of the metallic ions in soil and sediment samples around Oluyole area were observed to contain a varied concentration of Pb, Zn, Cu, Mo, Cr, Ni and Mn and it showed strong positive association with one another, which indicates that they have similar trend with metallic ions contamination in the study area. Several high concentration spots were identified in the geo-accumulation index maps. Most of the spots with high concentration of metallic ions where seen in an areas with high human activities, areas close to waste dump sites and mechanic workshops. In the industrial estate the means of effluent discharge was not directly into the river system in most cases but it is passed through the drainage into the river system. The evaluation of the level of contamination did not reflect that they are mainly from effluents but through other anthropogenic activities that occurred around the industrial estate although the possibility of geogenic input cannot be neglected. The influx of people through urbanisation and industrialisation into the industrial estate increases vehicular and commercial activities which in turn lead to waste dump site, mechanic workshops, and blacksmith workshops in the industrial estate. These induced secondary activities contributed to the increased heavy metals within the study area. The presence of Ona river within estate serve as discharge point for the industrial effluents though this study has clearly shown that the contamination seen are not directly from these industrial effluents but rather due to inflow of dissolution from the waste dump and mechanic waste and discharge into the stream. Hydrogeochemical characterization revealed an increase in HCO_3 and Ca^{2+} compared with SO_4^{2-}, though this study and the results from the water analysis revealed that the water falls within the maximum permissible limit of the WHO [7] for water quality.

Acknowledgements

The author is grateful to Oluyole and Ibadan South East Local Government authority for the assistance rendered during the sampling exercise for this study. Also, the author will like to mention the M.Sc students that went to the field with the author.

Figures 1-13

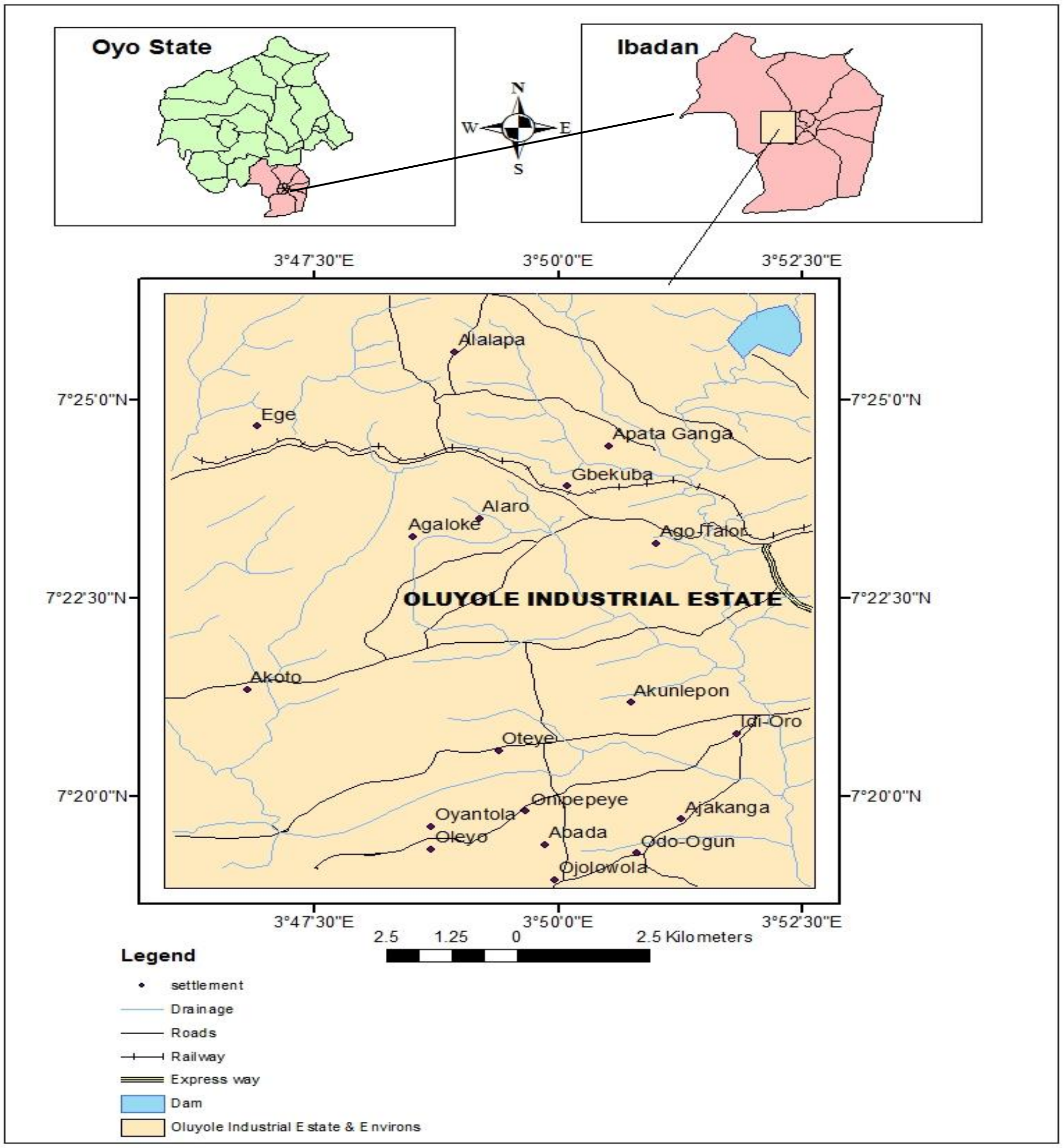


Fig. 1. Location Map of the study area (inset is the maps of Oyo State and Nigeria)

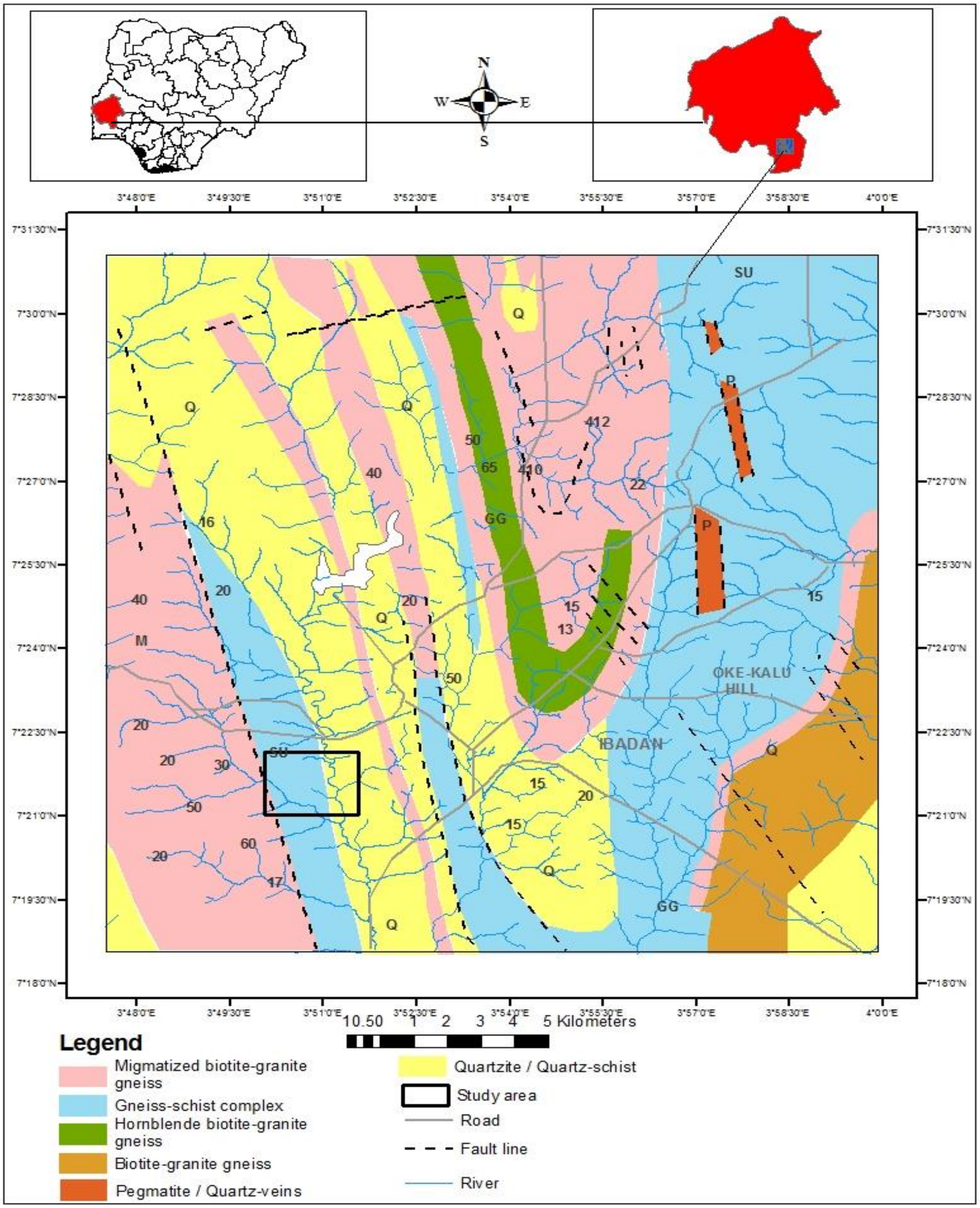


Fig. 2. Geological map of the study area (adapted from [1])

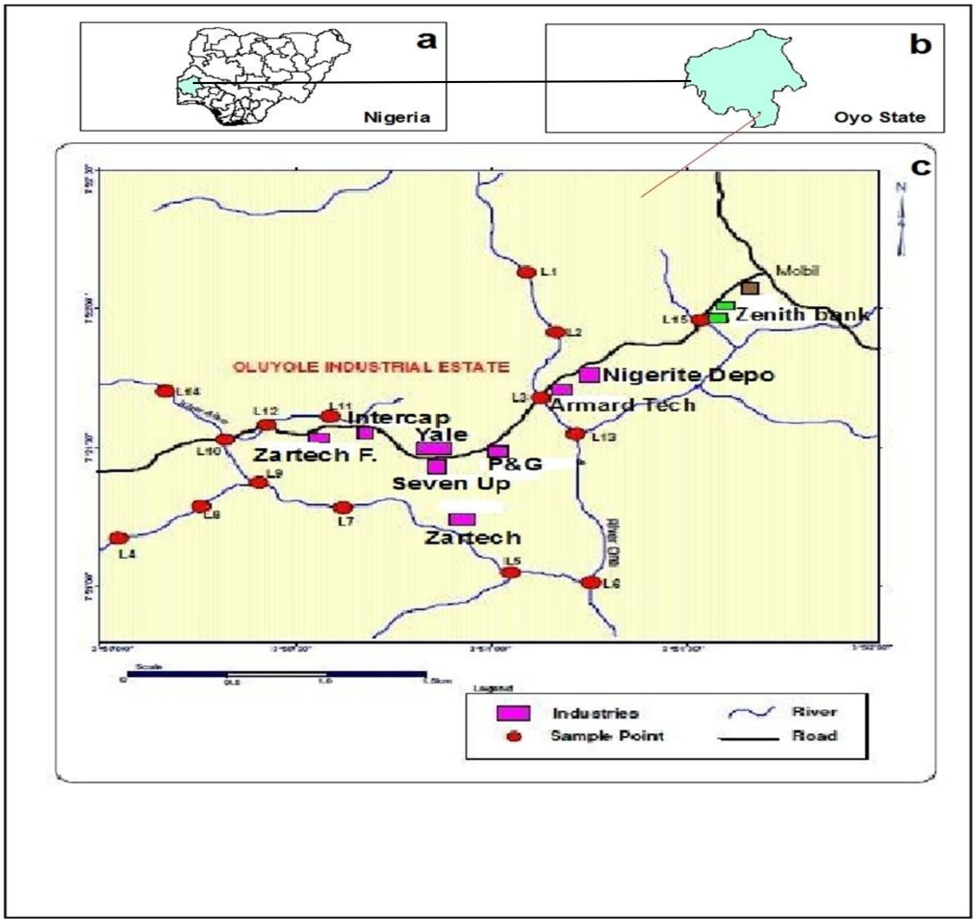


Fig.3. Map showing sampling locations within the study area.

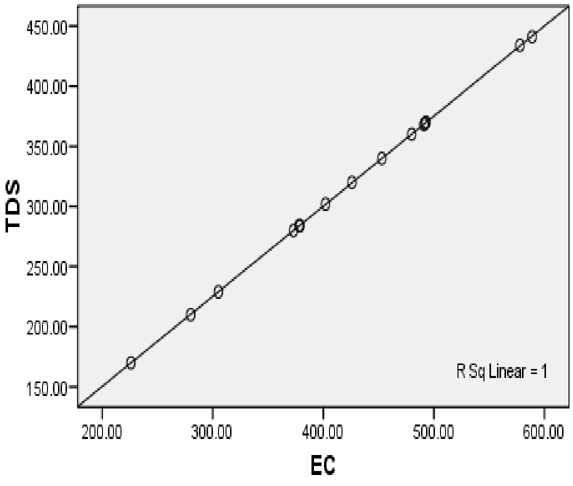


Figure 4. Plot of TDS versus EC

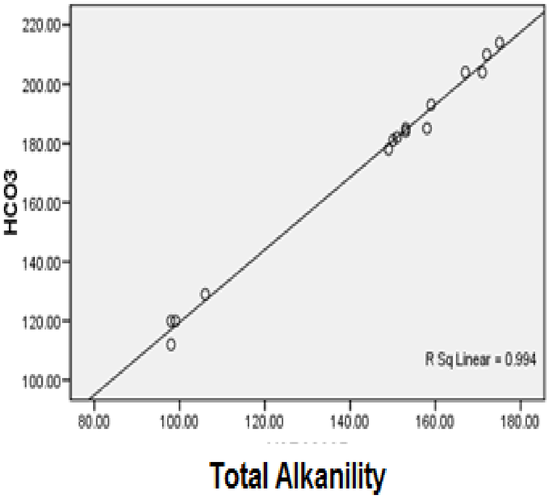


Figure 5. Plot of HCO_3 versus Total Alkalinity

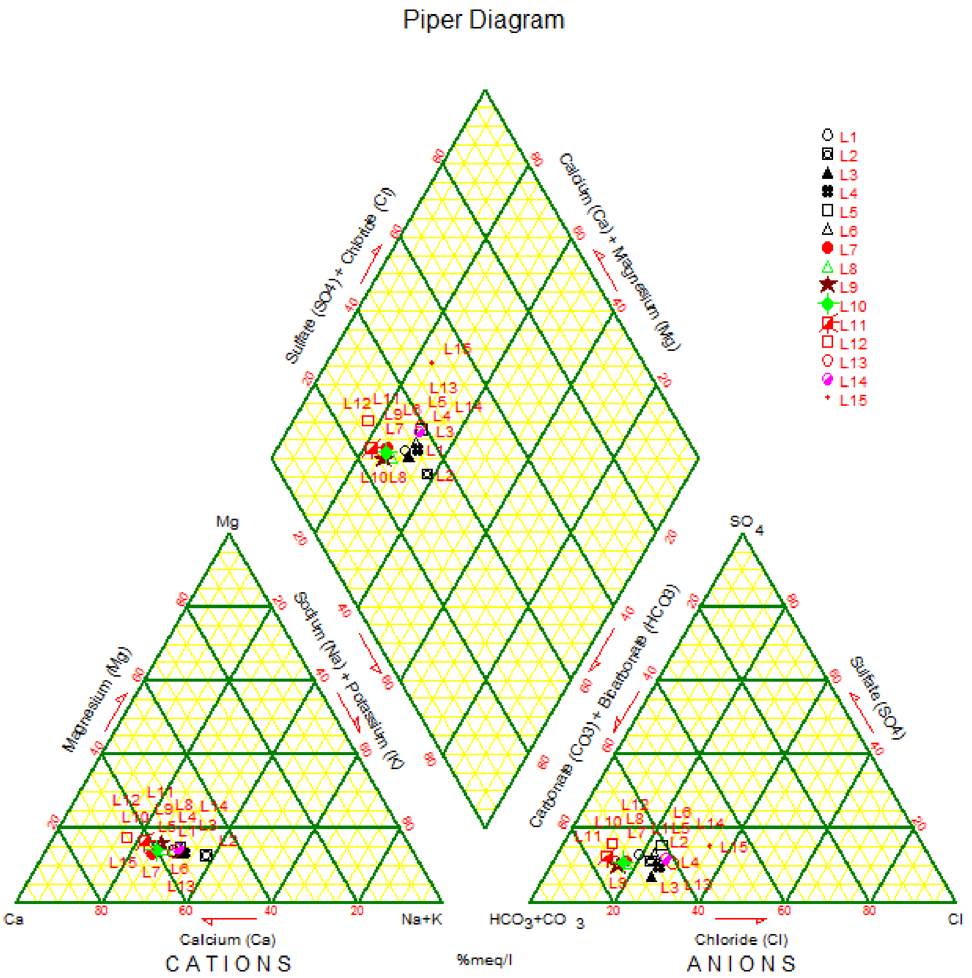


Figure 6. The chemical characters of the surface water in the study area (adapted from [10])

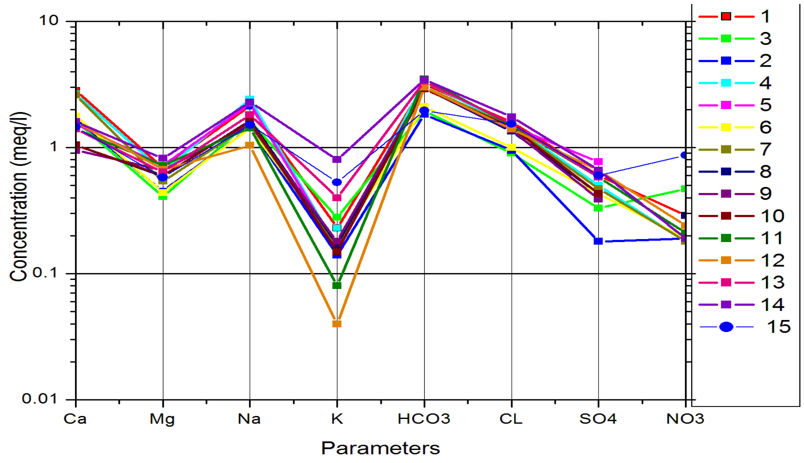


Figure 7. Schoeller diagram for water samples of the study area

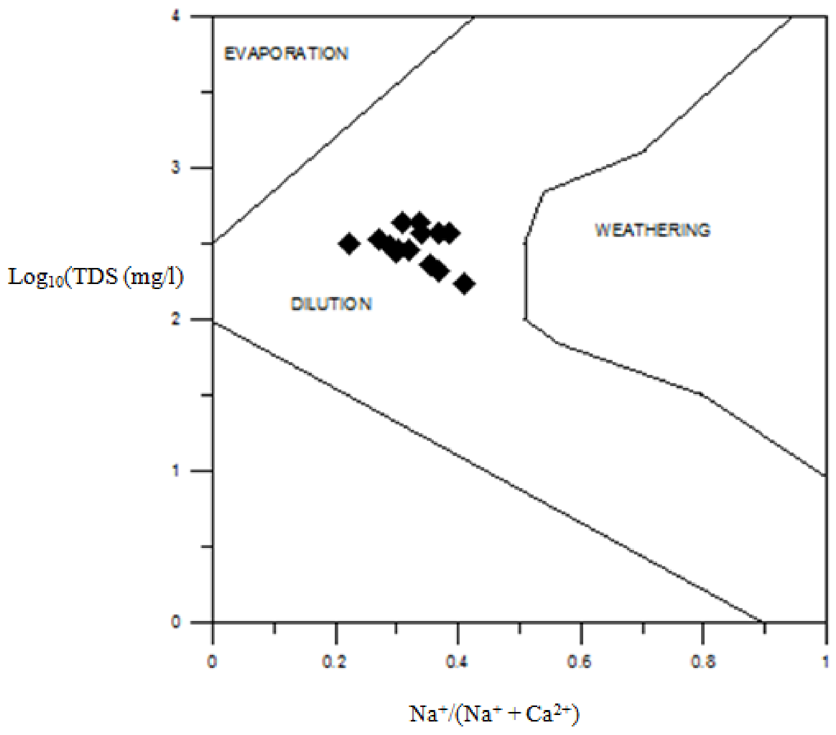


Figure 8: Gibbs diagram for weathering and dissolution of minerals

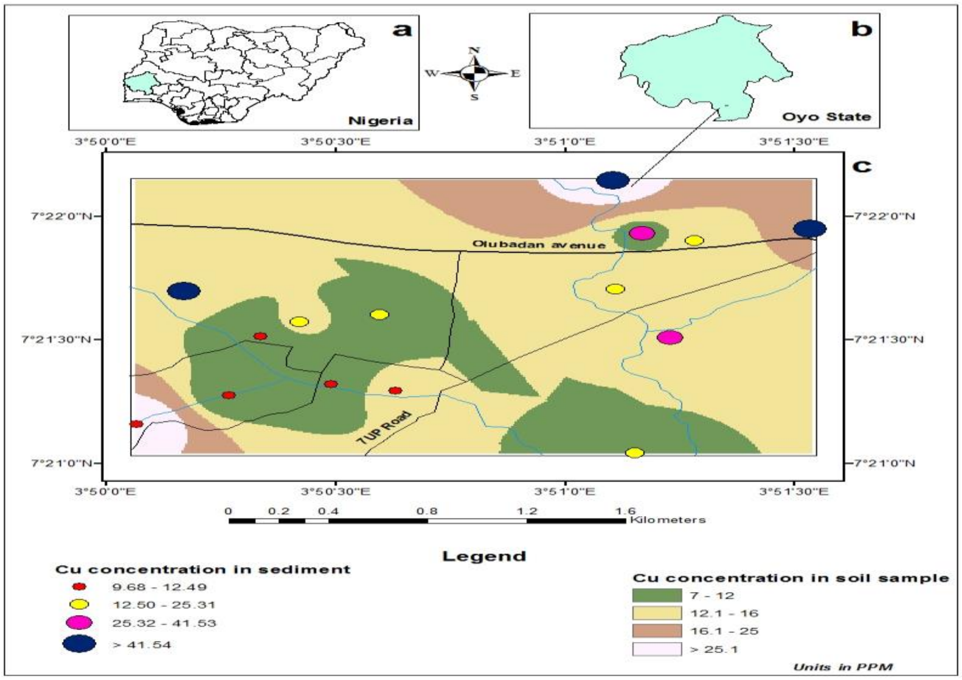


Fig. 9. Distribution pattern of Cu in soils and sediments

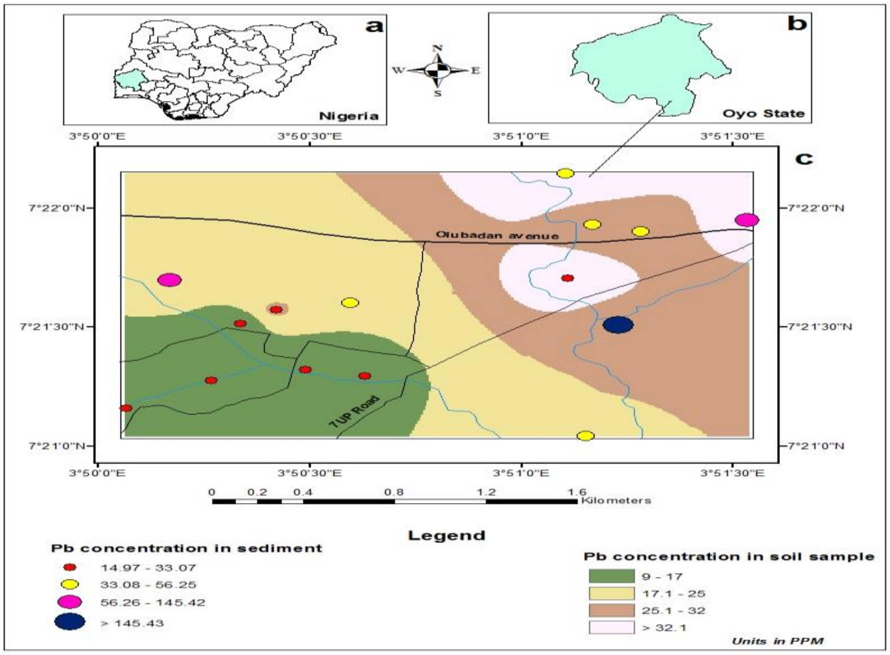


Fig. 10. Distribution pattern of Pb in soils and sediments

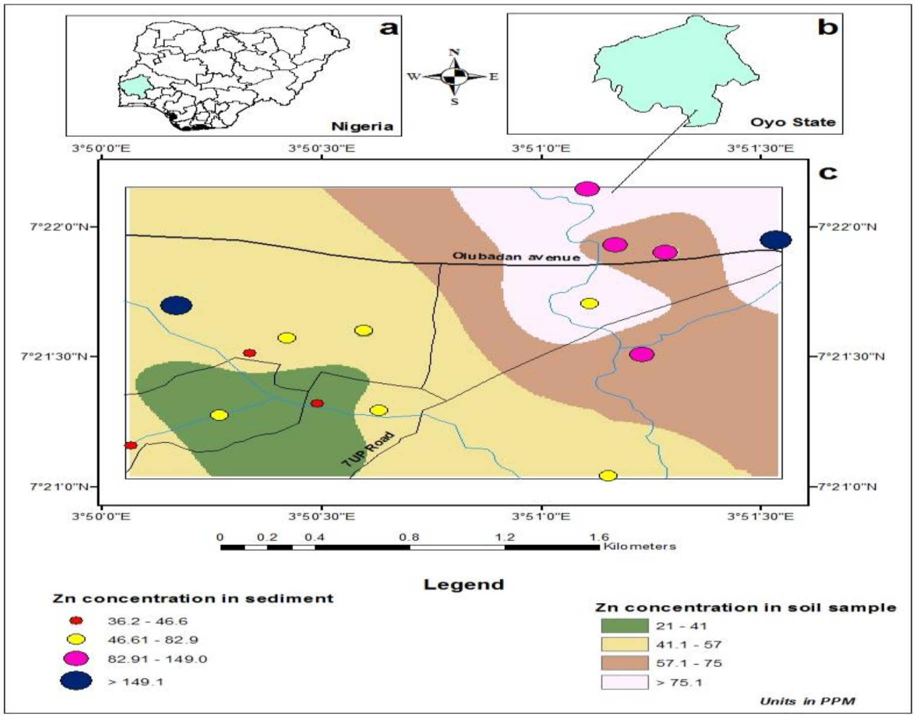
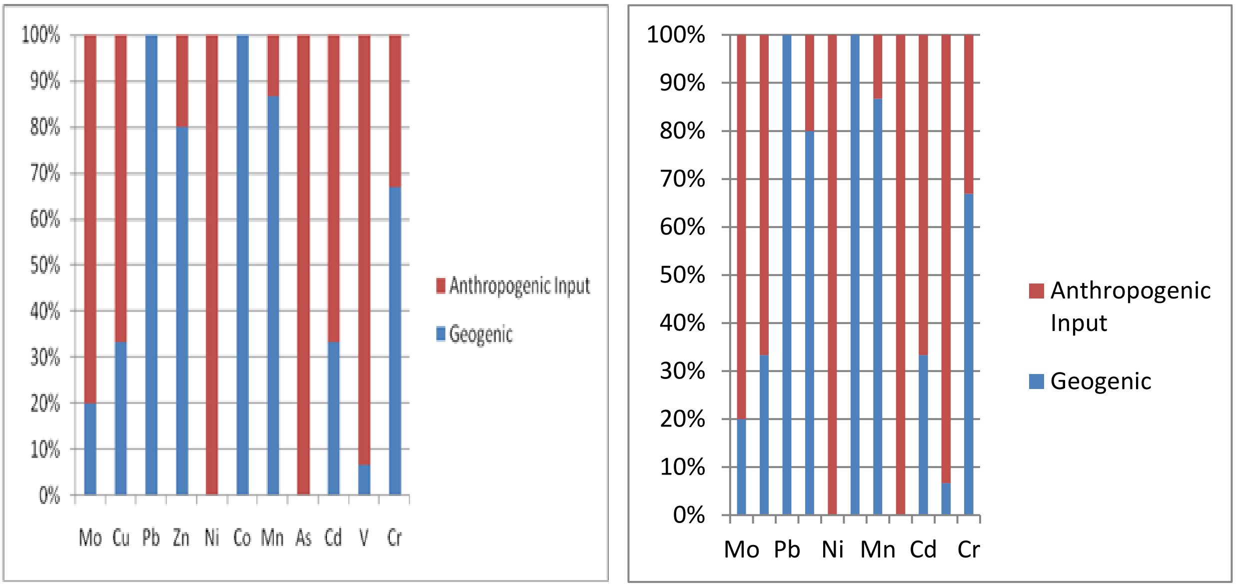


Fig. 11. Distribution pattern of Zn in soils and sediments

Fig 12. Pictures of probable sources of contaminants in the study area: (A) mechanic workshop (B) Automobile painting workshop (C) Parking lots for Motor cycles with preponderance of engine oil spills (D) Effluents discharge pipe from an industry within the study area (E) Direct effluent discharge from the Same Industry (F) Direct discharge of effluents into River Ona.



Figs 13(a) Sources of heavy metals in soils (b) Sources of Heavy metals in sediments

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Correspondence address: Dr Olubunmi C. Adeigbe, Department of Geology, University of Ibadan, Ibadan, Nigeria. +234-8028218932. olukris2009@gmail.com