Hydrogeochemical Evaluation of Water and Stream sediments in selected Drainage Systems of Oyo Township Southwestern Nigeria.

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Abstract: The indiscriminate dumping refuse along drainage systems in Oyo town has long made it known to be a repository of different pollutants including heavy metals. 15 streams and sediment samples of selected drainage systems of Oyo Township Southwestern Nigeria were analysed for Lead (Pb), Zinc (Zn), Cadmium (Cd), Iron (Fe) and Chromium (Cr) using Atomic Absorption Spectrophotometer (AAS). Results from this stream and sediments analysis were used to calculate some quantitative indices like Index of geo- accumulation (Igeo) and contamination factor .The ranges of heavy metals for stream water samples are Pb (0.02 - 70.45 mg/l), Cd (0.01 - 48.67 mg/l), Cu (0.03 - 67.20 mg/l), Fe (0.00 - 34.50 mg/l) and Zn (0.03 - 9.80 mg/l). Similar values for stream sediments were Pb (0.04 - 129.96 mg/l), Cd (0.06 - 44.12 mg/l), Cu (0.09 - 295.20 mg/l), Fe (0.03 - 20.78 mg/l) and Zn (0.09 - 16.80 mg/l). The trend of dominance revealed by the heavy metals concentrations in the analysed stream sediments are in the order: Pb > Cd > Cu > Fe > Zn > Cr. It was noted that Pb and Cu constituted the major contaminants in the stream sediment and Pb and probably Cu in stream water. However, in the stream water, Zn and Cr Contamination Factor also indicated low contamination level as these metals occurrence in the water revealed very low concentration which in turn resulted in zero CF in all the analyzed water samples. Relatively high geoaccumulation index values of Pb, Cd and Cu were peculiar to sediments within the densely populated areas of the study area where high rate of wastes are thus generated and in turn dumped on dumpsites. The concentrations of metals revealed impact of untreated waste discharges on stream sediment over the respective baseline concentration. Public awareness programs introduced through the print and electronic media and focused especially on the less educated is required to discourage some societal and cultural practices that contribute to geo- contamination.

Keywords: Drainage systems, Stream water ,Sediment,Metals, Anthrogenic source, Oyo Township,

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Introduction

Civilization and high population rate in major towns and cities has led to indiscriminate generation and disposal of vast amount of wastes. The most challenging is the indiscriminate disposal of wastes generated by industrial and anthropogenic activities into the ambient environment. There are potential risks to environment and health from improper handling of wastes, after some years, a dumpsite undergoes biologically, chemically, geologically, and hydrogeologically mediated changes resulting in a weathering process. Consequently, it becomes point source for pollution of the aquiferous units close to them (Manjunathan *et. al,* 2001). Human existence on earth is almost impossible without the heavy metals, even though important to mankind, exposure to them during production, usage and their uncontrolled discharge into the environment has caused lots of hazards to man, other organisms and the environment itself (Jarup, 2003). The indiscriminate dumping of municipal wastes along floodplains is common in Oyo town (Adewoye,2014). Drainage systems have long been known to be a repository of different pollutants including heavy metals, they retain over time the suspended sediments and particles that had adsorbed heavy metals, which are transported by erosion from various sources and afterwards redistribute the pollutants into the nearby water bodies (Zhang *et al*., 2015). Heavy metals are important determining factor of health conditions of living organisms and humans because, once introduced to the natural environment, they undergo biological accumulation. Heavy metals pollution is a critical environmental issue in riverine systems of many developing countries like Nigeria, as rivers are perceived as best disposal means for liquid and solid wastes of domestic and industrial sources (Ogedengbe and Akinbile, 2004) even when the input wastes is beyond the natural self-cleansing capacity of the rivers.

Study Area

Oyo township lies in the coordinates of N07˚ 47' 02" – N07˚ 62' 01" and E03˚ 52' 01" – E04° 00' 00" (Figure 1). Oyo is well accessible as there are well developed road networks in the town. The study area falls within the humid and sub-humid tropical climate of southwest Nigeria. The study area experience two seasons, rainy and dry seasons. Oyo Township lies on the Basement Complex area of southwestern Nigeria, comprising undifferentiated Gneiss – migmatite complex (Oyawoye, 1972). Rock exposures in the Oyo Township are generally underlain by quartzite, undifferentiated schist, magmatic gneiss and migmatite (Figure 2). The quartzites occur as long elongated ridges trending NW-SE and are mostly massive. The gneisses are the most dominant rock type. They occur as granite gneisses and banded gneisses with coarse to medium grained texture. Noticeable minerals include quartz, feldspar and biotite. Pegmatites are common as intrusive rocks occurring as joints and vein fillings. The rocks are highly fractured both at the surface and at depths making the drainage to be fracture controlled.

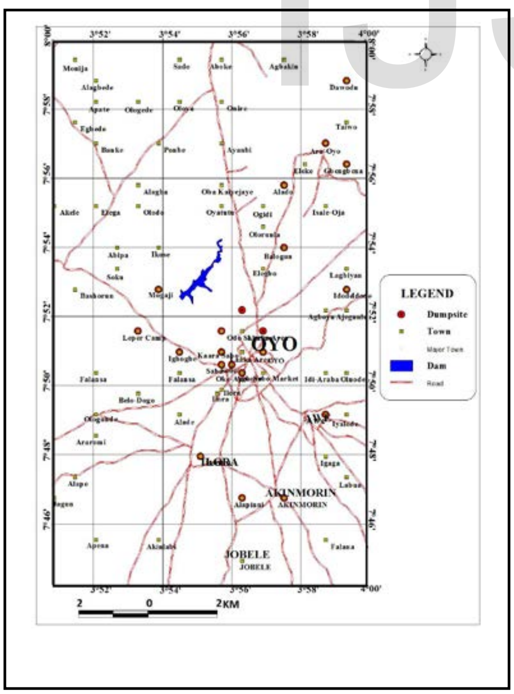

Figure 1:Local Geology of the Study Area.

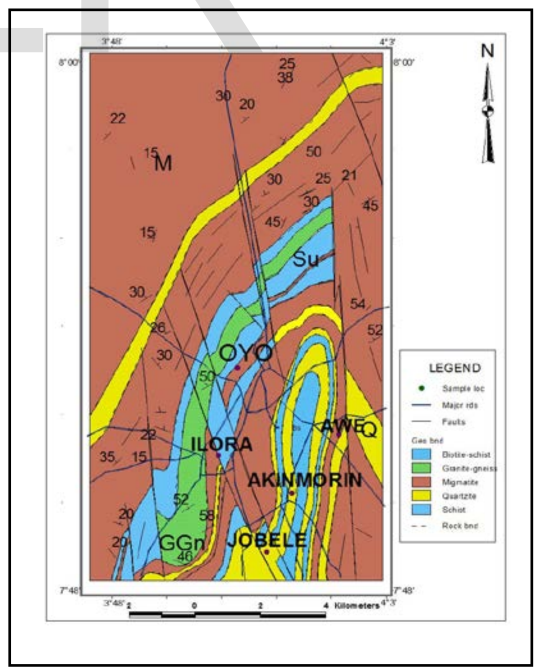

Figure 2: Geology Map of Oyo Township

Methodology

Sample Collection, Digestion and Analysis

A total number of fifteen samples were taken at the bottom of the sediments and the corresponding stream water samples were collected for hydrogeochemical analyses. The coverage of these locations was controlled by the even distribution within urban drainage network and accessibility. Water samples were collected in plastic bottles following the sampling procedure. Physical parameter (Temp, pH, Ec) were determined using pH meter and conductivity meter. Surface water samples were acidified prior to analysis of dissolved metal concentrations. The stream and sediment samples were collected in clean polythene bags using plastic shovel and sieves to avoid contamination and later air dried in the laboratory, disaggregated and sieved to obtain the clay fraction. The use of fine portions is as a result of their role as metal accumulators due to their net negative change and participation in sorption and caution exchange processes. The trace metals were analyzed using ICP-AES method. Results from this stream and sediments analysis were used to calculate some quantitative indices like Index of geo- accumulation (Igeo), Enrichment Factor (EF) and contamination factor which was used to evaluate degree of contamination as discussed below:

$$PLI = (C_{F1} \times C_{F2} \times C_{F3} \times .... \times C_{Fn})^{1/n} \quad (1)$$

Where n is the number of metal studied and C_F is the contamination factor for each metal.

Thomilson *et al*., (1980) categorized PLI into three; <1 = perfection; 1 = baseline level of pollution and >1 = deterioration of site quality

Contamination Factor was calculated using the formula:

$$C^1 f = C^1 0 - {}^1/_{C_B} \quad (2)$$

Where $C^1 0 - 1$ means concentration of element;
C_B Means background Concentration.

Where C_m and B_m are defined above while 1.5 is a factor for possible variation in the background concentration due to lithologic differences. B_m –background concentration of metal m either taken from literature (average crustal abundance) or directly determined from a geologically similar area. C_m – measured concentration in sediment or water.

Table 1: Classes of contamination degree by Hakanson (1980)

Classes	Contamination Degree (Cdeg)
Cdeg < 8	Low degree of contamination
8 < Cdeg < 16	Moderate degree of Contamination
16 < Cdeg < 32	Considerable degree of Contamination
32 < Cdeg	Very high degree of Contamination.

Index of Geoaccumulation, (Muller, 1981) was employed to evaluate the degree of metal contamination using results obtained from stream sediments analysis. It was computed using the expression

$$Igeo = \log_2\left({C_m}/{(1.5 \times B_m)} \right) \quad (3)$$

Table 2: Classification of contamination factor by Hakanson (1980).

Class	Indication
$C^1 f < 1$	Low contamination Factor
$1 < C^1 f < 3$	Moderate Contamination Factor
$3 < C^1 f < 6$	Considerable Contamination Factor
$6 < C^1 f$	Very high Contamination Factor

Results and Discussion

Metal Concentration

The trace metals of selected surface water in Oyo Township was presented in Table **3**. Pb, Cd, Fe and Cu had high concentrations compared to background and control values. (Figure 3 & 4) highlights the variability of the trace metals in the study area. There was an indication of the fact that sources of metal contamination are related to anthropogenic point sources inputs through the indiscriminate dumping of metal scraps, batteries, market wastes on the dumpsites and these find their ways into the river courses. The general trend of dominance revealed by the heavy metals concentrations in the analyzed stream sediments are in the order: Pb > Cd > Cu > Fe > Zn > Cr. It was noted that Pb and Cu constitute the major contaminants in the stream sediment and Pb and probably Cu in stream water. A comparison of the heavy metal contents of the study area with the control sample at Sabo area shows that the studied area is contaminated. Although Pb, Zn, Cu and Cd occur naturally in soils, stream sediment, surface and groundwater (Elueze, 2001). Inputs from anthropogenic activities could be responsible for their roles as potential pollutants to the site. Results from stream water and sediments analyses were used to calculate Index of geo-accumulation (Igeo) and contamination factor.

Index (Igeo) and Contamination Factor (CF) were employed to assess the level of sediment and stream water contamination. The concentration of each element in the control sample represents the respective background value for all the indices applied. Some of the analyzed heavy metals in stream sediments have their concentrations greater than their respective concentration in the control sample. This is an indication that most of these heavy metals may have been derived from other sources in addition to underlying bedrocks. Metals have been known to come from both natural and anthropogenic sources, natural occurrence of metals and geographic mineralogical variation often hamper the accurate assessment of anthropogenic input of metals (Hwang *et al*, 2009). Relatively high values of Pb, Cd and Cu were peculiar to sediments within the densely populated areas of the study area where high rate of wastes are generated and in turn disposed on dumpsites.

Table 3: Statistic Summary of heavy metal Concentration in stream sediment and stream water

ORIGINAL STREAM WATER AND SEDIMENT

S/N	LOCATION	Zn	Cu	Cd	Pb	Cr	Fe	ZINC	COPPER	CADMIUM	LEAD	CHROMIUM	IRON
1	SADO	1.20	5.50	2.62	0.60	1.81	0.07	3.24	8.4	0.43	0.02	0.30	0.08
2	AKINMORIN	3.40	22.80	2.26	6.92	0.18	8.9	13.4	16.8	1.54	34.51	1.06	7.78
3	ILORA	4.50	28.80	10.26	8.74	0.22	1.7	15.6	19.8	2.22	60.07	1.54	2.81
4	IYALAMU	6.80	22.80	0.26	6.92	0.18	8.93	8.8	27.9	3.14	84.82	2.17	7.89
5	KAARA	8.80	32.10	33.62	65.60	1.81	34.5	5.46	27	3.03	112.78	2.10	12.67
6	ILORA	0.80	31.60	5.97	16.50	4.14	15.6	6.76	42.8	4.81	129.96	3.33	17.22
7	AWE	5.90	18.20	8.71	12.60	3.26	8.3	12.7	9.4	1.11	29.85	0.77	9.21
8	ARA OYO	4.45	62.40	0.70	18.93	0.49	1.34	2.12	1.3	1.50	4.00	1.04	3.33
9	OYO	9.80	21.57	24.60	21.70	3.28	8.96	16.8	2.6	2.97	80.09	2.05	8.54
10	LAGUNA	2.70	51.60	0.58	15.65	0.40	7.6	6.34	8.4	4.81	129.96	3.33	9.45
11	OLORUNDA	0.10	67.20	0.76	20.39	0.52	3.4	2.54	10.4	1.17	31.67	6.56	4.99
12	AJEGUNLE	4.90	33.60	0.38	10.19	0.27	8.92	5.76	295.2	3.32	89.56	2.30	7.43
13	MOGAJI	6.90	22.90	5.02	13.60	3.47	8.76	2.78	30.23	0.34	9.10	0.23	5.45
14	SABO	2.30	43.70	44.12	70.45	5.62	20.78	2.67	37.2	0.42	11.29	0.29	26.78
15	ELEGBO	2.80	38.40	0.43	11.65	0.30	3.45	1.87	158.4	1.78	48.05	1.23	2.89
16	CONTROL	0.09	0.03	0.01	0.02	0.06	0.001	0.07	1.41	0.03	0.03	0.04	0.12
	SUM	64.24	497.70	137.67	299.85	24.19	141.14	106.91	697.24	32.62	855.77	28.35	126.64
	AVG	4.28	33.18	9.18	19.99	1.61	9.41	6.68	43.58	2.04	53.49	1.77	7.92
	MAX	9.80	67.20	44.12	70.45	5.62	34.50	16.8	295.2	4.81	129.96	6.56	26.78
	MIN	0.09	0.03	0.01	0.02	0.06	0.00	0.07	1.3	0.03	0.02	0.04	0.08

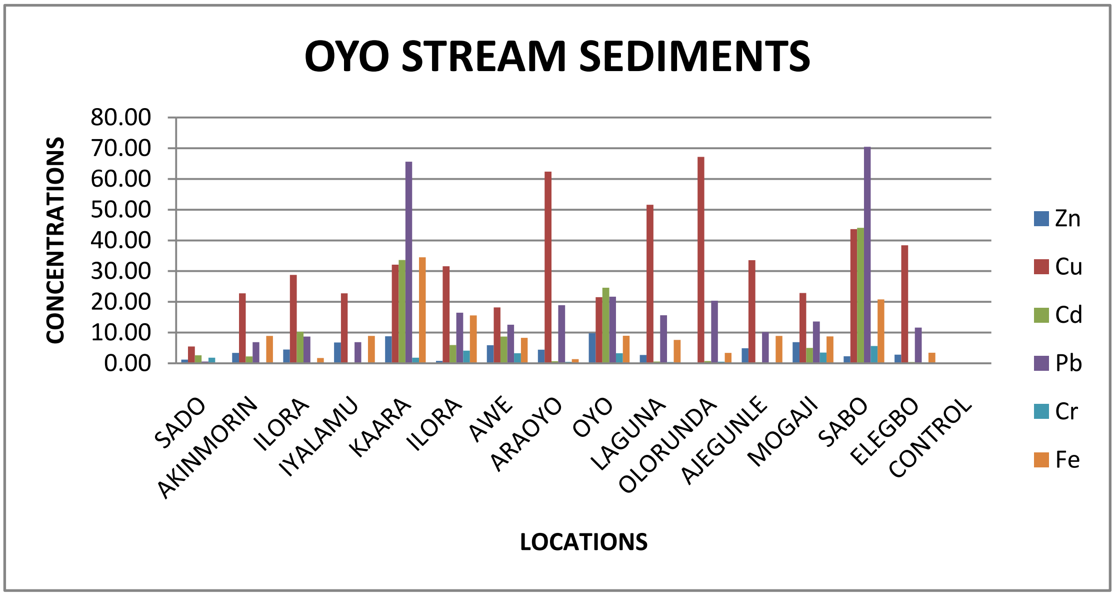

Figure 3: Variation of the Metals in the stream sediments

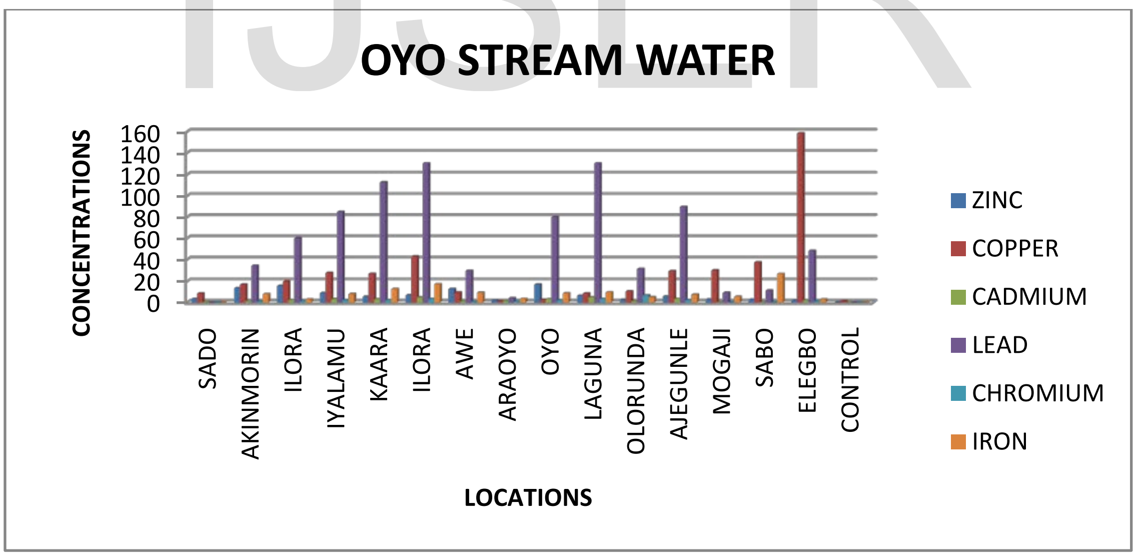

Figure 4: Variation of the Metals in the Stream Water

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Contamination Factor

The assessment of sediment contamination was carried out using the Contamination Factor. In the version suggested by Rastmanesh *et al.*,(2010) and Atiemo *et al.*,(2011), an assessment of sediment was conducted through ratio of the concentrations in the stream sediments to concentration in the control sample which represent the Background value for this study

$$C^i_r = C_i / C_n^i$$

Where C_r^i is the Contamination Factor of the metal of interest, C_i is the concentration of the metal in the sample while C_n^i is the background concentration. In consonance with this study, the Average Crustal Value was used by Taylor and Meclennan, (1985).

The Table 4 presents the range of CF of the heavy metals in stream water and stream sediment of the study area in the stream sediment, Zn and Cr Contamination Factor indicated low contamination level as these metals occurrence in the sediments revealed very low concentration which in turn resulted in Zero CF in all the samples. Cu Contamination Factor ranged from 0 to 2. In Awe sample, the CF measures 0 indicating low contamination. CF measures 2 in Ara-oyo and Olorunda indicating moderate contamination Factor while it measures 1 in all other locations indicating moderate contamination factor. Cd contamination factor ranged from 2 to 8 indicating that some areas had high contamination factor. In addition to Olorunda, Ara-oyo, Laguna and Ilora are places with significant high contamination. Pb contamination factor ranged from 0 to 4, Iyalamu and Sabo had the highest contamination factor of Pb indicating considerable contamination factor.

However, in the stream water, Zn and Cr contamination factor also indicated low contamination level as these metals occurrence in the water revealed very low concentration which in turn resulted in zero CF in all the analysed water samples. Cu contamination factor ranged from 1 to 11. Iyalamu, Kaara, Ilora, Oyo and Laguna revealed CF category in the very high contamination side. Moderate contaminations were recorded in Olorunda, Araoyo and Awe while considerable contamination factor were measured in Akinmorin and Elegbo.

Table 4: Range of Contamination Factor of the Heavy Metals in Stream water and Stream sediment

		Stream sediments		Stream water	
Element	*Background	Minimum	Maximum	Minimum	Maximum
Cu	39	0.0	2.0	1.0	11.0
Pb	17	0.0	4.0	0.0	8.0
Zn	67	0.0	0.0	0.0	0.0
Cd	0.1	2.0	8.0	1.0	5.0
Cr	69	0.0	0.1	0.0	0.0

*In this study Average Crustal Value of Taylor &Maclennan, 1985 was used as the respective Background Value

Cd contamination factor ranged from 1 to 5 indicating that some areas are having very high contamination factor. Places where very high Cu contamination factor were measured such as Iyalamu, Kaara, Ilora, Oyo, Laguna, Olorunda, Araoyo and Awe had considerable/moderate contamination factor. Pb contamination factor ranged from 0 to 8. Iyalamu and Sabo recorded the highest CF of Pb indicating extremely contamination factor. For each of these elements, contamination factor for stream sediments and water were produced using different tones of color to emphasize variations in concentrations in different locations. Figures 5a- 5h are the Contamination Factor maps produced for these heavy metals.

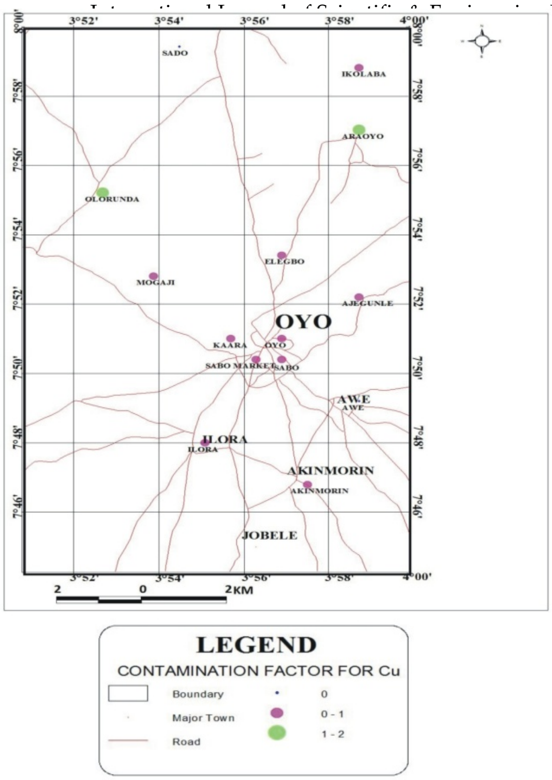

Fig. 5a: Contamination Factor map of Cu concentration in sediments of Oyo Township

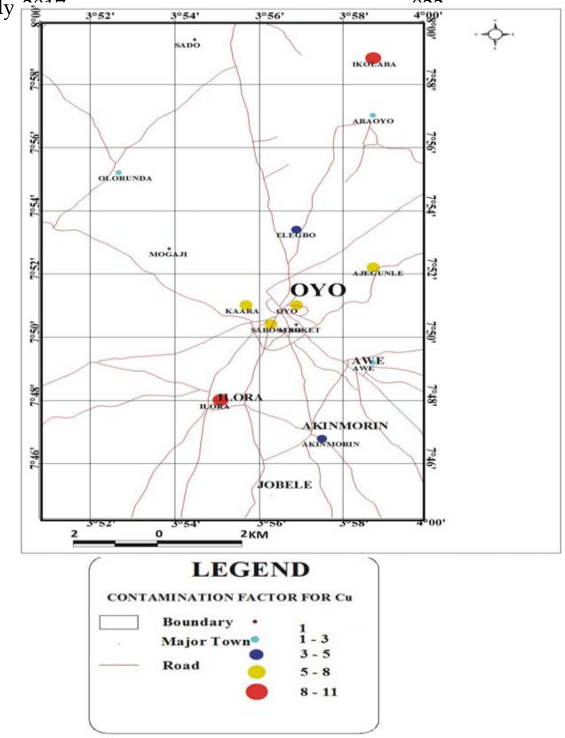

Fig. 5b: Contamination Factor map of Cu concentration in stream water of Oyo

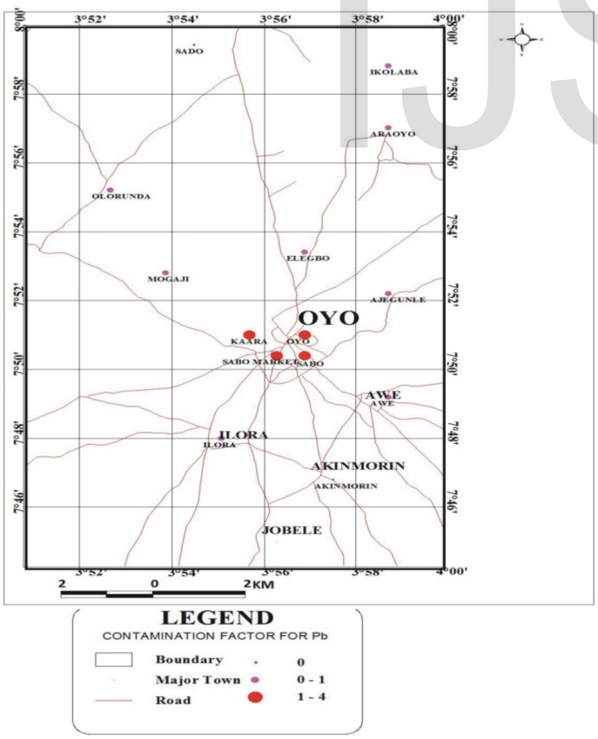

Fig. 5c: Contamination Factor map of Pb concentration in sediments of Oyo Township

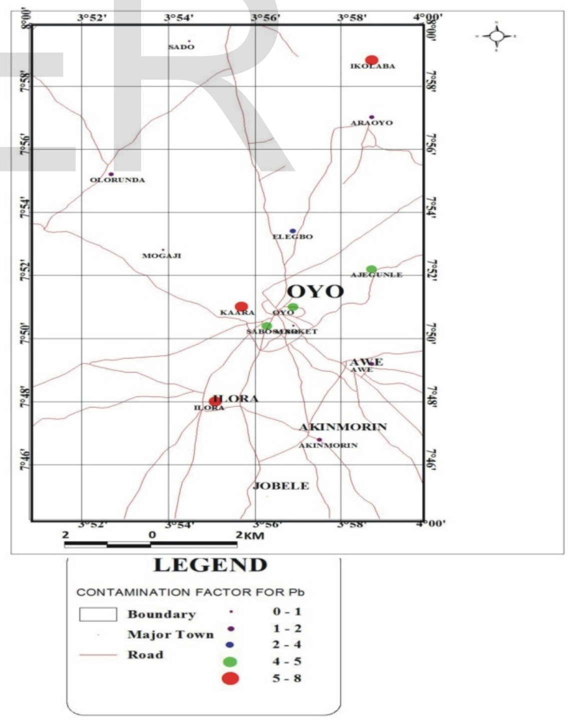

Fig. 5d: Contamination Factor map of Pb concentration in stream water of Oyo Township

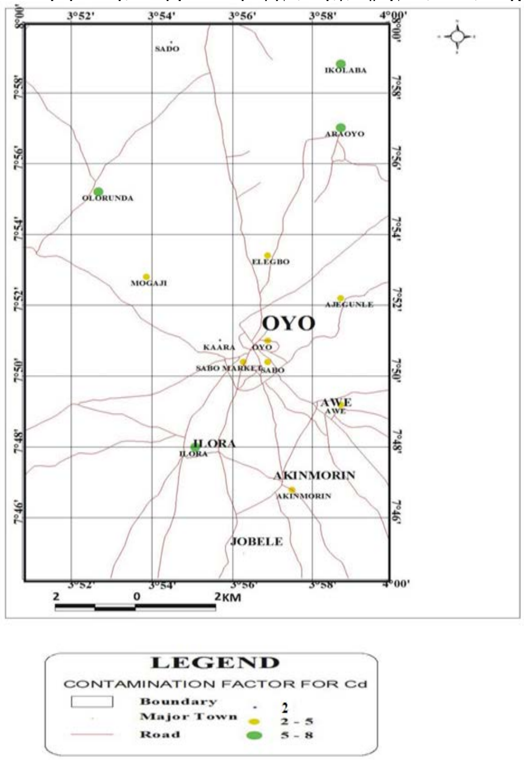

Fig. 5e: Contamination Factor map of Cd concentration in sediments of Oyo Township

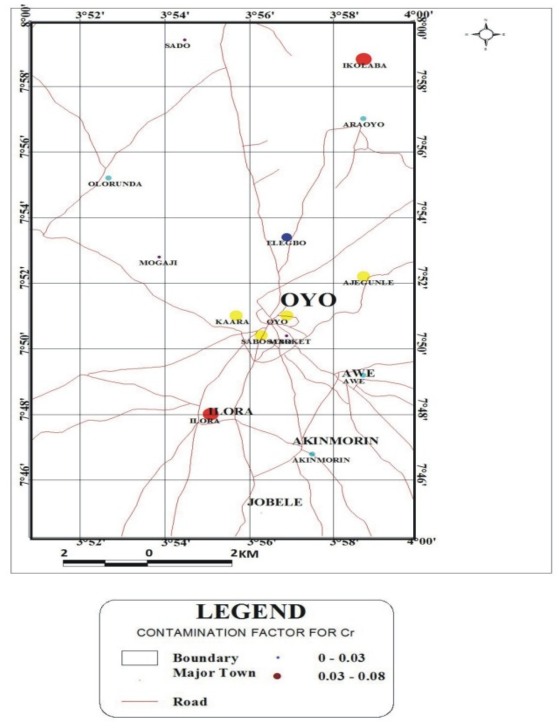

Fig. 5f: Contamination Factor map of Cd concentration in stream water of Oyo township

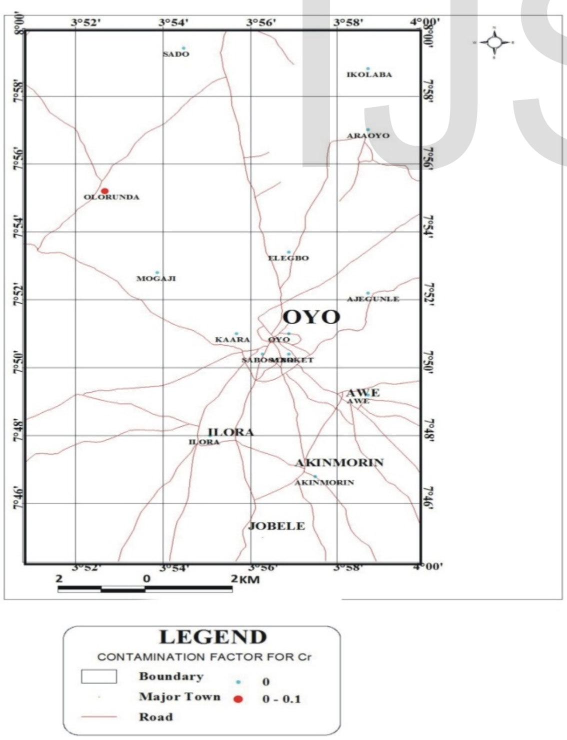

Fig. 5g: Contamination Factor map of Cr concentration in sediments of Oyo Township

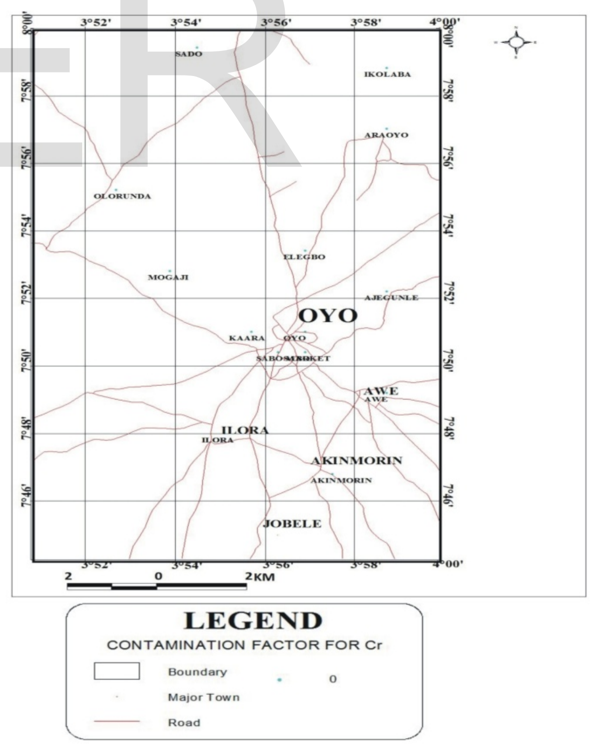

Fig. 5h: Contamination Factor map of Cr concentration in stream water of Oyo Township

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Geoaccumulation Index

In the trace metals of surface water in Oyo Township, Pb, Cd, Fe and Cu had high concentrations compared to the background and control values, this trend highlighted the variability of the trace metals in the study area. There was strong and clear indication of the fact that sources of metal contamination were related to anthropogenic point sources inputs through the indiscriminate dumping of metal scraps batteries, market and mechanic wastes on the dumpsites; all these find their ways into the river courses. The general trend of dominance revealed by the heavy metals concentrations in the analyzed stream sediments are in the order: Pb > Cd > Cu > Fe > Zn > Cr. It was noted that Pb and Cu constituted the major contaminants in the stream sediment and probably in the stream water.

A comparison of the heavy metal contents of the study area with the control sample at Sabo area suggested that the studied area is contaminated. Although Pb, Zn, Cu and Cd occur naturally in soils, stream sediment, surface and groundwater (Elueze, 2001); inputs from anthropogenic activities could be responsible for their roles as potential pollutants to the site. The variation of the trace metals in the stream sediment is a further confirmation of the anthropogenic point source inputs. The geo-accumulation index comprises of six classes ranging from uncontaminated to extremely contaminated classes (Table 5). Table 6 presents the range of Igeo of the heavy metals in stream water and stream sediments of the study area. The percentage of different classes of geo-accumulation was calculated and presented in Table 7. In the stream sediment, Cr Igeo indicated practically uncontamination level of the metal in the medium as their

occurrences in the sediments revealed very low concentration which in turn resulted in < 0 Igeo for Cr in all the samples (Figure 6a); likewise Igeo for Cu indicated uncontaminated to moderately contaminated level of the metal in all samples (Figure 6b). Pb Contamination Factor ranged from 0 to 4.7, in Ilora, Oyo and Laguna measured Igeo greater than or equal to 4 belonging to Igeo Class 5 which indicated heavy to extreme contamination of these environments while all other places except Sabo and Elegbo were atleast moderate to heavily contaminated with Pb because these places have Igeo values greater than 2 (Figure 6c). Zn Igeo ranged from 0 to 1.99, Ilora sample is the only point where Igeo measured 2, a value that is insignificantly different from Igeo 0 to 1.99. (Figure 6d).

Table 5: Geo-accumulation Index Classes proposed by Muller, 1981

Classes	Ranges	Indications/Soil quality
0	Igeo<0	Practically Uncontaminated
1	0<Igeo<1	Uncontaminated to moderately contaminated
2	1<Igeo<2	Moderately contaminated
3	2<Igeo<3	Moderately to heavy contaminated
4	3<Igeo<4	Heavily contaminated
	4<Igeo<5	Heavily to extremely contaminated
6	5<Igeo	Extremely contaminated

Table 6: Range of Igeo of the heavy metals in stream water and stream sediment

	Igeo	Stream sediments		Stream water	
Elements	*Background	Minimum	Maximum	Minimum	Maximum
Cu	39	-1.7	0.2	-1.0	2.9
Pb	17	-1.0	4.7	-4.7	6.0
Zn	67	-9.9	1.99	-5.6	-0.1
Cd	0.1	0	5.1	1.2	5.0
Cr	69	-8.8	0.0	-9.1	-0.00

Table 7: Percentage of Igeo class of the selected trace metals in stream sediments and water

Value	Class of Igeo	Cu	Pb	Zn	Cr	Cd
Igeo≤0	0	98	13.3	100	100	20
0<Igeo<1	1	-	60	-	-	13.3
1<Igeo<2	2	2	-	-	-	13.3
2<Igeo<3	3	-	13.3	-	-	-
3<Igeo<4	4	-	13	-	-	-
4<Igeo<5	5	-	-	-	-	13.3
5<Igeo<6	6	-	-	-	-	40

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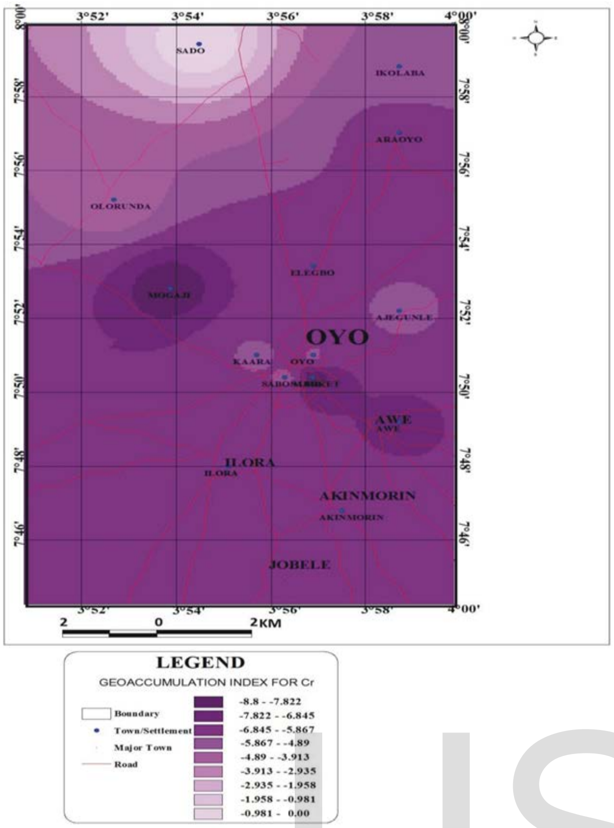

Fig. 6a: Geoaccumulation Map of Cr Concentration in sediments of Oyo Township

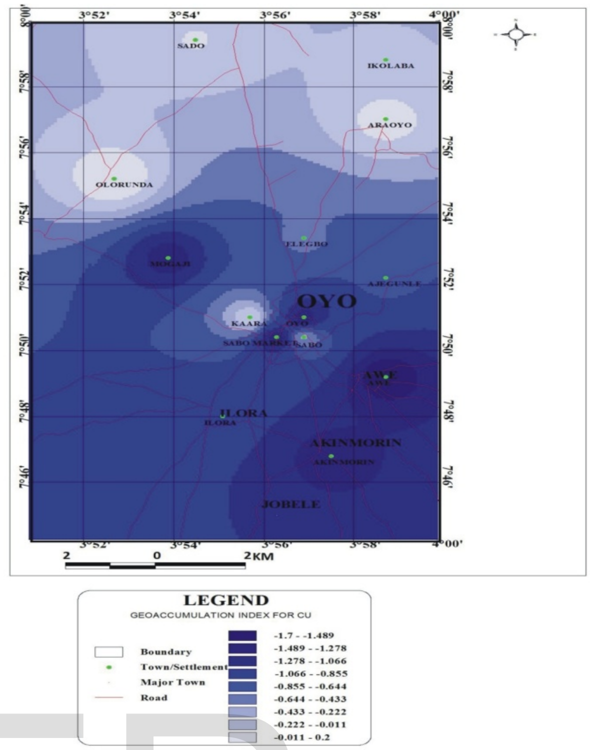

Fig. 6b Geoaccumulation Map of Cu Concentration in sediments of Oyo Township

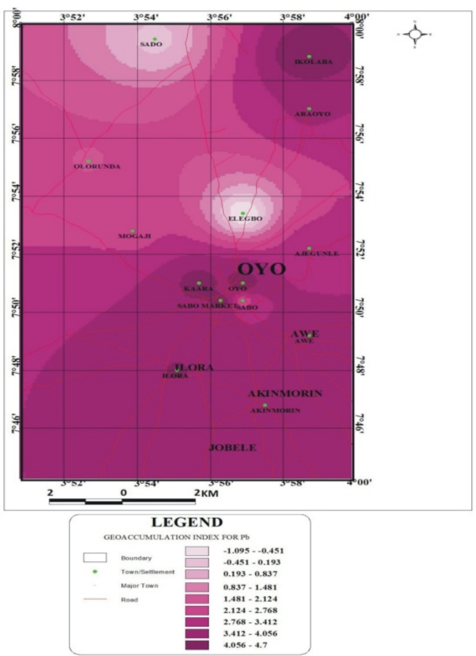

Fig. 6c: Geoaccumulation Map of Pb Concentration in stream sediments of Oyo Township

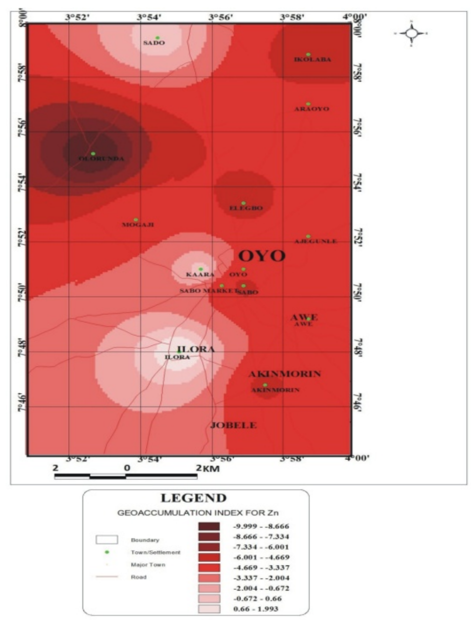

Fig.6d: Geoaccumulation Map of Zn Concentration in sediments of Oyo Township

However, in the stream water, Cr and Zn Igeo revealed an uncontaminated level of the metal in the medium as their occurrences in the sediments recorded very low concentrations which in turn resulted in < 0 Igeo for Zn and Cr in all the samples (figure 7a-7d). Cd Igeo ranged from 1.2 to 5.0, Ajegunle, Laguna, Oyo, Kaara and Iyalamu samples recorded Igeo of 4 to 5, belonging to Igeo Class 5 which opined heavy to extreme Cd contamination of these environments while all other places (except Mogaji and Sabo recorded Igeo of 1 to 2 of Igeo Class 3 which suggested moderate Cd contamination of these environments) recorded Igeo of 3 to 4 belonging to Igeo Class 5 which predicted heavy Cd contamination of these environments. Pb Igeo ranged from < 0 to 6.0, Kaara and Sabo markets had Igeo greater than 5 of Igeo Class 6 which indicated heavy to extreme Pb contamination of these environments while all other places except Akinmorin, Ilora, Ara-oyo and Elegbo were atleast practically uncontaminated with Pb probably because these places have Igeo values less than zero. Cu Igeo varied from < 0 to 2.9, a value that suggested practically uncontaminated to moderate/heavy contamination level.

There is dearth of information on the trace metal concentrations of stream sediments of Oyo Township.There are variations in the colors of the samples, the studied sediments had low silt content. The results of the trace element geochemistry of the stream sediments revealed that elements like Pb and Cd were significantly enriched above their background concentrations in Oyo Township while other metals like Zn, Cu and Cr have their concentrations within the range of background concentrations. Evaluations of the heavy metals contents revealed that Pb and Cd are metals that are of environmental significance. In terms of the geo-accumulation values , the stream sediments of Oyo Township could be described as slightly contaminated with Cu, Zn and Cr and moderately to heavy contaminated with Pb and Cd. All these contamination indices indicated that areas around the dump sites are densely populated and of high commercial activities and are significantly enriched in Pb and Cd, these were mostly found in the central part of the study area. The general environmental implication of the metal concentrations in the study area showed that it is uncontaminated to moderately contaminated with Zn, Cu and Cr, and heavily contaminated with Pb and Cd.

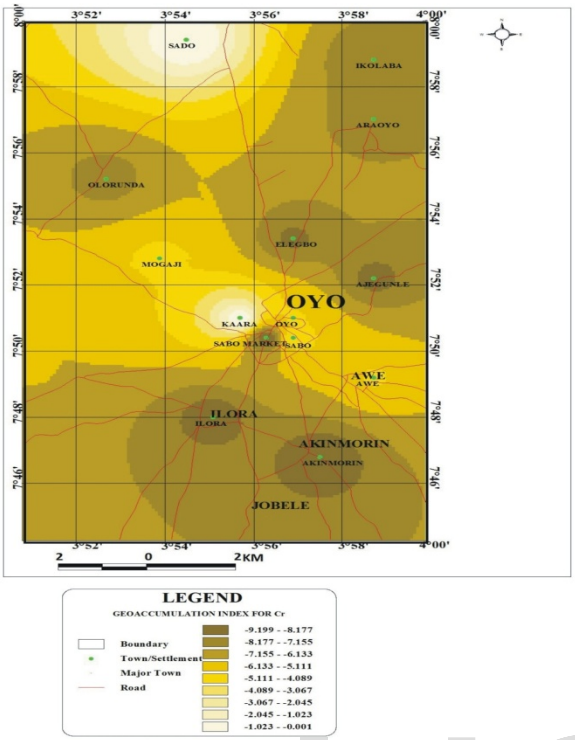

Fig. 7a: Geoaccumulation Map of Cr Concentration in stream water of Oyo Township

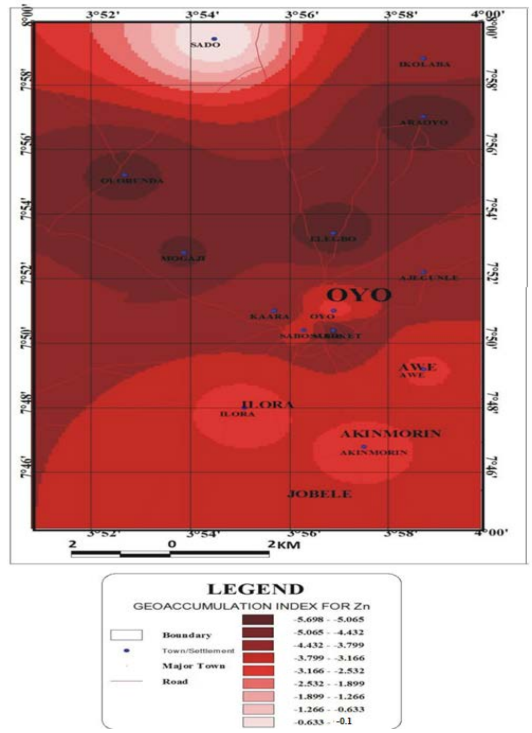

Figure 7b: Geoaccumulation Map of Zn Concentration in stream water of Oyo Township

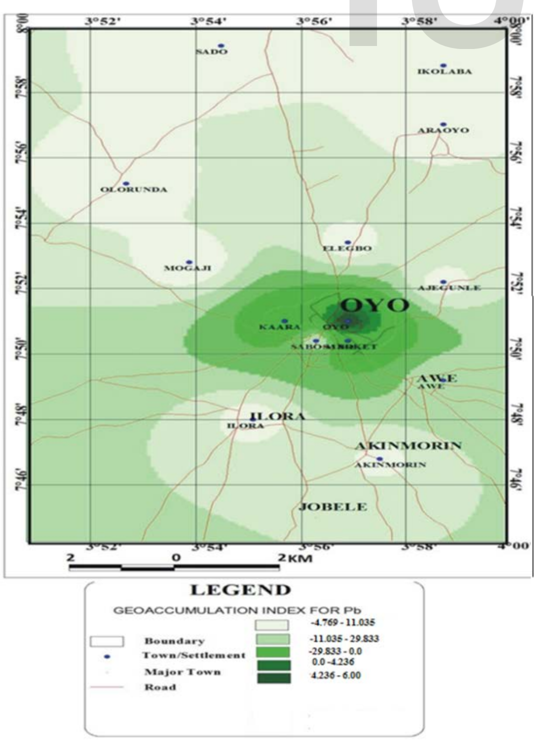

Fig. 7c: Geoaccumulation Map of Pb Concentration in stream water of Oyo Township

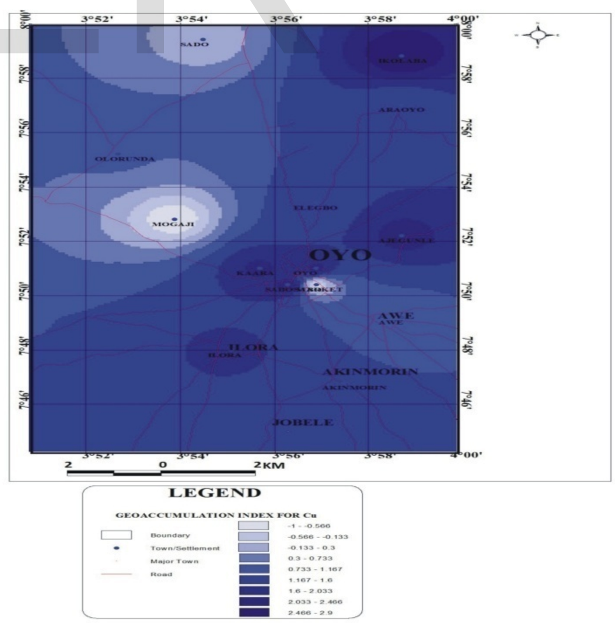

Fig. 7d: Geoaccumulation Map of Cu Concentration in stream water of Oyo Township

Conclusion

The study highlighted the influence of anthropogenic activities in terms of trace metals contamination of urban drainage systems management practices of Oyo Township. Assessment of urban drainage system in Oyo Township revealed impact of untreated waste discharges on dissolved trace metals concentration and the enrichment of the trace metals in the stream sediment over the respective baseline concentration. Assessment of trace element contamination in the stream sediment and water samples using quantitative indices such as geoaccumulation degree showed that the area around the waste dump have been moderately to highly contaminated with trace metals such as Cu, Pb and Cd. Geoaccumulation index maps revealed enriched Igeo for Cd and Pb for stream sediment and water within the high traffic density zones, densely populated and waste dumps. The above heavy metals found in studied samples around the waste dump are toxic and very harmful to human. The uncontrolled disposed of metal scraps, lead acid batteries probably caused the relatively high level of Pb and Cd found in stream water and sediment. The study highlighted the influence of anthropogenic activities in terms of trace metals contamination of urban drainage systems management practices of Oyo Township. Assessment of urban drainage system in Oyo Township revealed impact of untreated waste discharges on dissolved trace metal concentration and the enrichment of the trace metals in the stream sediment over the respective baseline concentration. Public awareness programs should be introduced through the print and electronic media to discourage some societal and cultural practices that contribute to geo- contamination.

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