Geochemical distribution of heavy metals in soils and stream sediments of Omiyale and environs, Ibadan, southwestern Nigeria

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Abstract: An assessment of geochemical distribution of heavy metals in soils and sediments of Omiyale was done to elucidate their effect on plants and animals in the study area. Nine (9) soil samples and four (4) stream sediments were randomly collected, sieved with the 63um sieve and analyzed using the inductive coupled plasma mass spectrometry (ICP-MS) technique. Fe_2O_3 is dominant in the stream sediment used as waste disposal tanks. Influence of anthropogenic enrichment was noticed from the index of geoaccumulation (I_{geo}) Zn (2.40), Pb (4.75); inter-elemental analysis Cu-Pb (0.6), As-Zn (0.7), and quantification of degree of pollution Pb (62.2%) in soil, Pb (44.6%) in stream sediment with an increasing order Zn>Pb>Ba>Cu>As>Cd. The study area is polluted with Pb and Zn attributed to urbanized anthropogenic sources, which are mostly vehicular emission, and domestic sewage. Public effect of these elements could include lung cancer and cardiovascular diseases. Based on the above evaluation, a recommendation in respect of public awareness program on sanitizations and contamination of quality control of soil and sediments are encouraged.

Key words: Anthropogenic, disposal tank, contamination, sanitization, urbanization

Introduction

Soils are produced from the breakdown of pre-existing rocks of Precambrian basement complex and are transported from one place to another by different media (Aweto, 1994). The chemistry of a soil is the cumulative reflection of its geology regionally, and locally, with the type and genesis of the weathered regolith (Zhang et al, 2002, Price & Velbel, 2003, Mitchell, 1974; Sharma & Rajamani, 2003), these factors will be responsible for the chemistry of loose sediment. Contaminants of surface drainage systems are mostly related to the consequences of population growth, urbanization, agricultural activities and development of new industrial zones **(**Olade 1987, Paul & Piilai, 1983), while uncontrolled direct dumping of domestic wastes and discharge of sewage into the urban drainage systems, inadequate land-use planning and improper waste disposal and management systems are critical components of heavy metals contamination (Ajayi & Mombeshora, 1990). However, the release of trace metals associated with such soil processes could have both positive and negative impacts on the environment (Fergusson 1990, Tiller 1989). The type of bedrock beneath the soil in an area can determine the kinds of trace elements present in vegetation, water and sediments in such an area; investigation of heavy metals in soil and sediment is therefore, essential since a slight change in the concentration above the acceptable level, whether due to geogenic (natural) or anthropogenic (man-made) sources like inadequate sewage facilities, road constructions, mining activities, traffic emissions, landfills, agro-chemicals, industrial effluents can result in serious environmental and subsequent health problems (Cobelo-Garcia et al, 2003, Fangueiro et al, 2002, Sandroni & Smith, 2002). Trace metal contaminated soil and sediments, therefore, represent a significant environmental concern which has been demonstrated to be toxic to soil/sediment-dwelling organisms, human health, and fishes resulting in decreased survival, reduced growth, or impaired reproduction, and lower species diversity (La Pointe & Hudson, 1985). In Nigeria, rapid population increase due to rural – urban migration in the last few decades, characterizes most of the big cites and urban centers. Unfortunately, poor sanitary and wastes/ sewage disposal facility had led to gradual degradation of the environment (Tijani et al, 2004).

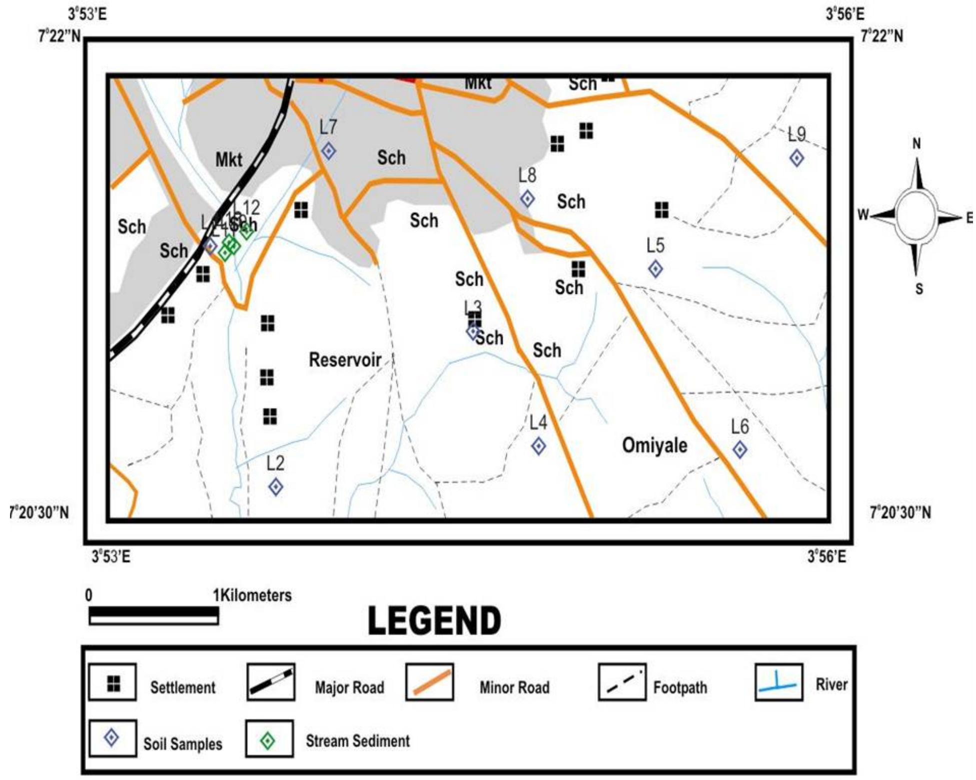

Fig.1: Map of the study area and location of sample points

Based on the above background, these study focuses on the contamination of heavy metals in the soil and sediments of the densely populated areas of Ibadan metropolis (Fig. 1), with the aim of assessing the implication of this contamination to the public health, and in addition examining the possible sources of contamination of the environment.

Materials and method

Nine (9) soil and four (4) stream sediment samples were taken at locations close to the groundwater samples (See fig.1); the soil and stream sediments were decanted and immediately bagged to avoid contamination; they were then air dried for seven days to reduce the rate of fungi growth contamination, and subsequently sieved with the 63µm mesh. The samples were analyzed using the inductive coupled plasma mass spectrometry (ICP-MS) technique.

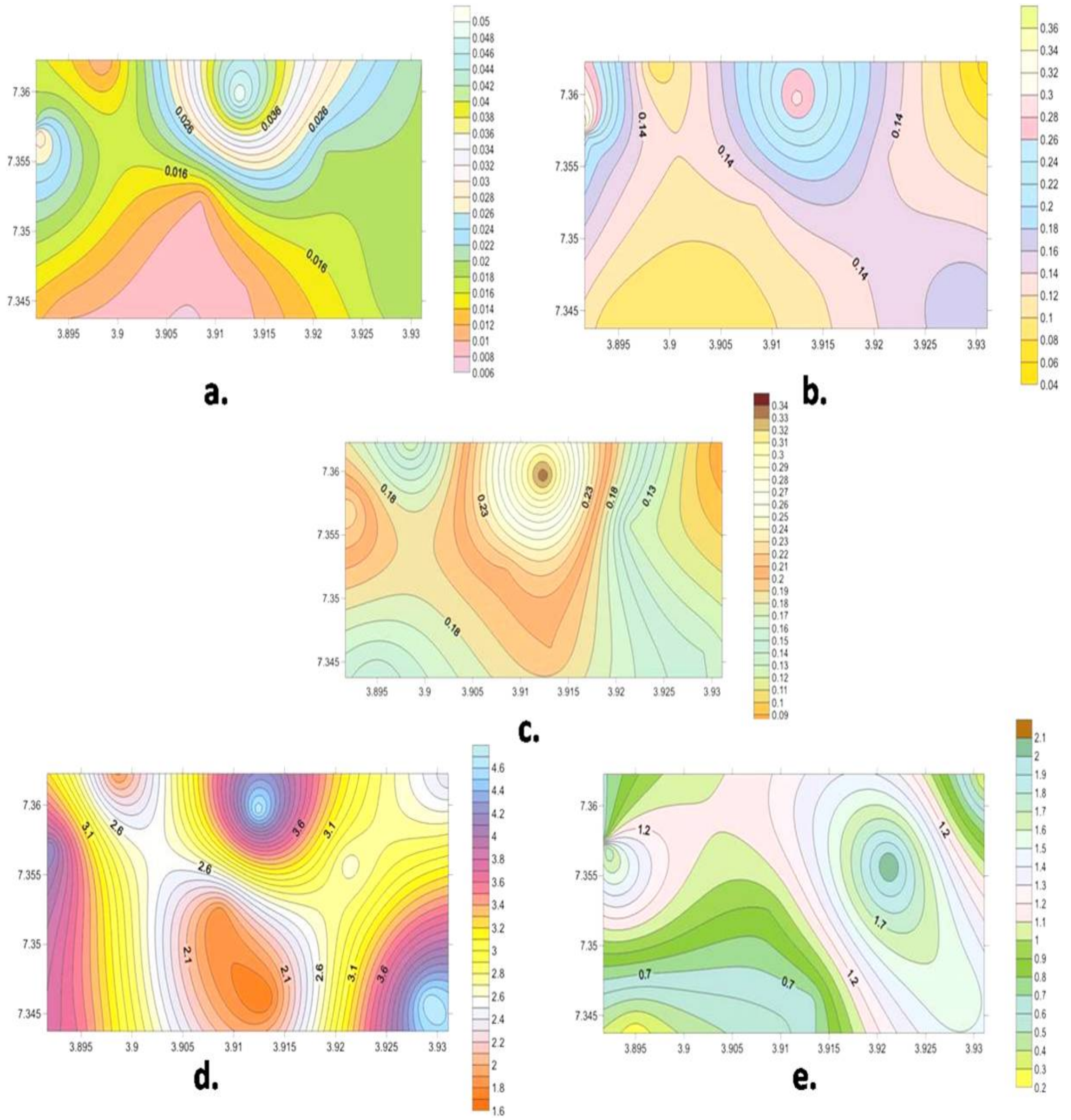

Fig.2: Geochemical map for concentration of (a)Na_2O, (b)MgO, (c) K_2O, (d) CaO and (e) Fe_2O_3 in the study area.

Result and Discussion

Soil chemistry

Major Oxides: Concentrations of the major oxides Table 1.0 of soil and sediments in the study area showed that Fe_2O_3 ranges from 3.30- 7.15% with mean of 5.23 in the sediment; 2.17-6.06% with mean of 4.04 in the soil; CaO ranges from 0.74-0.99% with mean of 0.84 in the sediment; 0.31-2.97% with mean of 1.48 in the soil; MgO ranges from 0.22-0.98% with mean of 0.41 in the sediment; 0.08-0.48% with mean of 0.27 in the soil; Na_2O ranges from 0.01-0.02% with mean of 0.02 in the sediment; 0.01-0.07% with mean of 0.03 in the soil; K_2O ranges from 0.17-0.36% with mean of 0.22 in the poor sanitary and waste/sewage disposal facilities in the study area where their stream channel is used extremely as the waste-disposal tank, sediment; 0.10-0.41% with mean

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of 0.22 in the soil. There is dominance of Fe_2O_3 in the sediments when compared to the soil (Fig. 2 & 3), in addition, the dominance of the other oxides (CaO, MgO, Na_2O, K_2O) in the soils was found in all the areas showed the oxides had been majorly contributed from the weathering of aluminosilicates, Ferromagnesian and aplite rich minerals of the rocks on the soil, Fig. 2 & 3 showed the geochemical maps of the oxides, and this reveals the impact of each oxide on the environment. A significant correlation also confirms the above revelation Table 2.0. Factor analysis, Table 3.0 of the soil and stream used to explain the underlying controlling variables (Hakanson, 1980) showed that the variables in factor 1 consist of all the major oxides, which shows that they are those controlling the chemical character of the soil and stream sediments, and they account for 57% of the total variance of the variables with Eigen value of 2.8; furthermore, the relatively high positive correlation is a reflection of the influence of community on the soil and stream sediment chemistry which affirms that the indiscriminate dumping of industrial and market sewage waste in the soils and sediments of the study area. Factor 2 consists of all the oxides except Fe_2O_3, K_2O suggests a natural environment for the oxides, but it still shows the influence of CaO on the chemistry. Factor 3, also affirms the same controlling environment for the oxides except for CaO and Fe_2O_3. This can be concluded that the chemical character of the soil and sediment is mostly the major oxides analyzed, but it is dominated by CaO and Fe_2O_3.

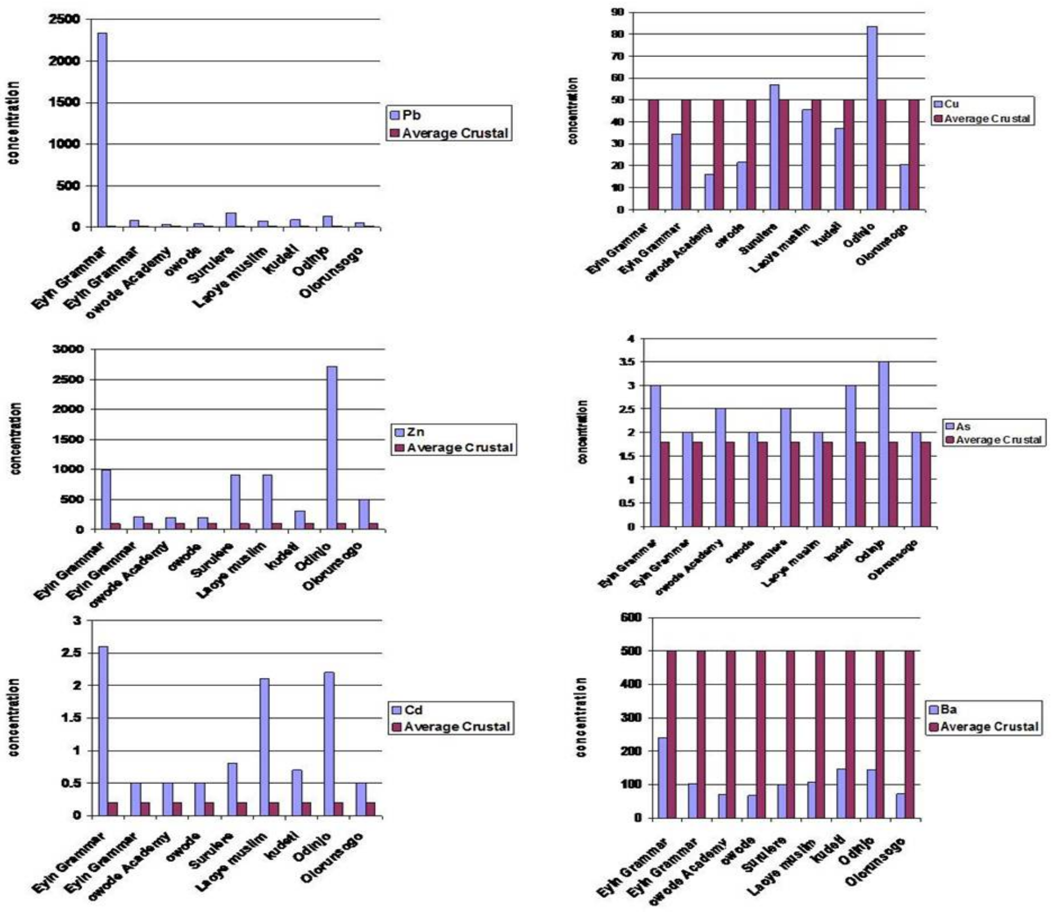

Fig 3: Bar chart concentration of Pb, Cu, Zn, As, Cd and Ba in the study area compared with crustal averages.

Trace Elements: mean concentrations for all the elements in both soil and stream sediment showed an increasing order of Zn>Pb>Cu>As>Cd. However, the concentration of trace elements in soil samples is quite higher compare to stream sediments. The highest concentrations were found in Elere River (LC13), Eyin Grammar (LC1) and Surulere (LC5) due to sewage sludge, steel and irons works and refuse incineration activities found within the area. The concentration of the metals when compared with their respective crustal average (Taylor, 1964) are higher than the recommended except for Ba (Table 4); since the samples taken are from areas that are densely populated, it, therefore, implies the metals are the product of human activities consequent upon supply from mini - industries such as soap making, plastic factory, battery making, steel and iron work industries. Fig.7. & 8 shows the comparison of the element with the crustal averages. There is strong and positive correlation (Table 5) among the metals Cu-Pb (0.6), Cu-Ba (0.6), As-Zn (0.7), Cd-As (0.6), Zn-Cd (0.7); these results thus buttress the anthropogenic and homogeneous nature of the source area. Fig.3 shows the comparison of each of the metals with the crustal average.

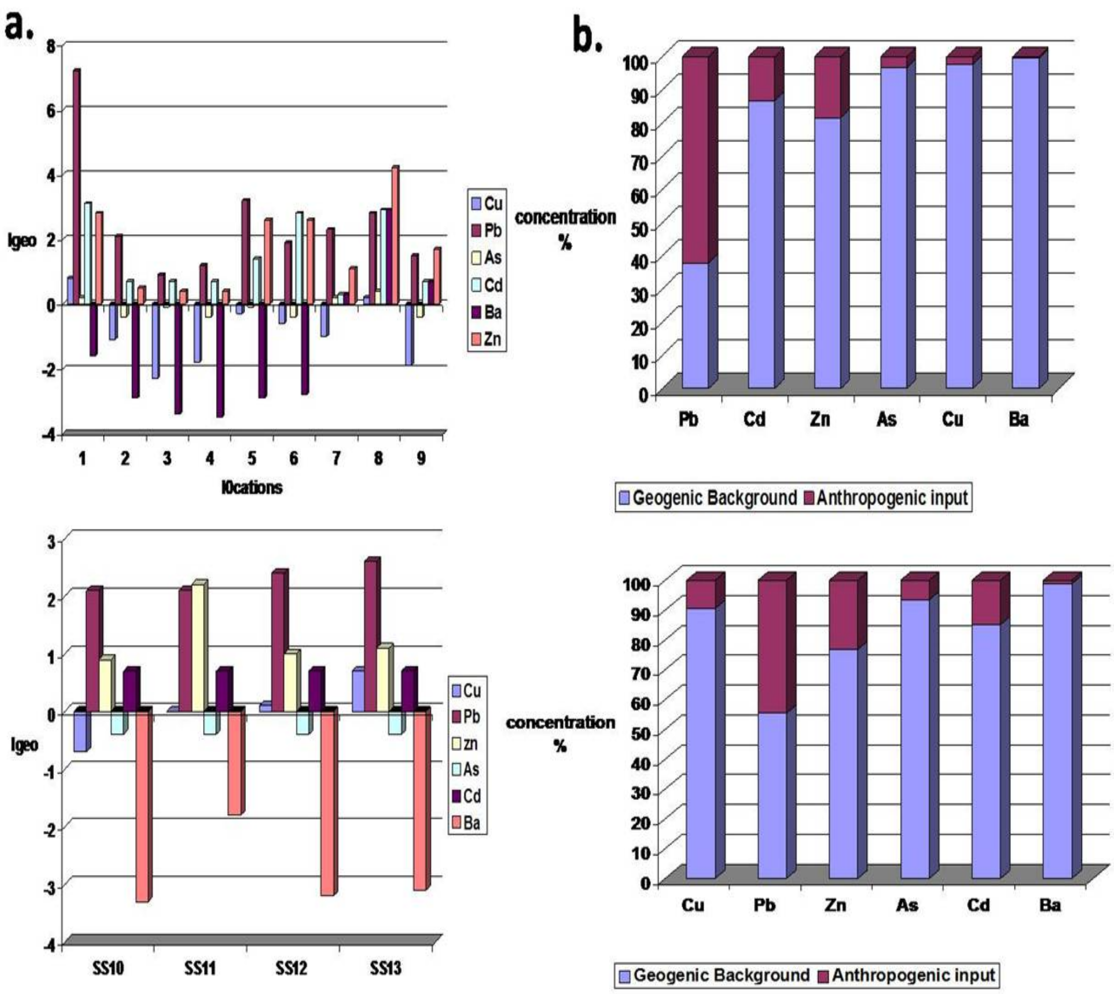

Fig.4a: Bar chart for the lgeo concentrations of trace elements for the samples. (b) Distribution of in-put sources of the trace elements in (a) Soil and (b) Stream sediments

Data Evaluation

For the assessment and quantification of the level of contamination in the various media studied, some quantitative contamination indices were used to describe the concentration trends, it and also allows for ease comparison between the determined parameters. These indices used include;

- Anthropogenic Factor (A.F)
- index of geoaccumulation (I_{geo}) and
- risk index.(K_o)

Anthropogenic Factor (AF)

The anthropogenic factor for soil (Table 6) showed that Ba (0.2) has low contamination; Cu (1.0) and As (1.4) and Cd (5.7) moderately contamination and Zn (7.9) and Pb (26.7) are high contamination

Table 1: Descriptive statistics of major oxides for the soil and stream sediment

Element	N	Range%	Minimum	Maximum	Mean
Fe_2O_3	s	2.17-6.06	2.17	6.06	4.04
	ss	3.30-7.15	3.3	7.15	5.23
CaO	s	0.31-2.97	0.31	2.97	1.48
	ss	0.74-0.99	0.74	0.99	0.84
MgO	s	0.08-0.48	0.08	0.48	0.27
	ss	0.22-0.98	0.22	0.98	0.41
Na_2O	s	0.01-0.07	0.01	0.07	0.03
	ss	0.01-0.03	0.01	0.03	0.02
K_2O	s	0.10-0.41	0.1	0.41	0.22
	ss	0.17-0.36	0.17	0.36	0.22

ss- stream sediments, s- soil

Table 2: Correlation Coefficient of major oxides for the soil and stream sediment

	Na_2O	K_2O	Fe_2O_3	CaO	MgO
Na_2O	1				
K_2O	.623*	1			
Fe_2O_3	.453	.454	1		
CaO	.521	.221	.159	1	
MgO	.479	.786**	.628*	.165	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Table 3: Factor Analysis of major oxides for the soil and stream sediment

	Component		
	1	2	3
Na_2O	.810	.353	-
K_2O	.860	-	-.411
Fe_2O_3	.730	-	.609
CaO	.464	.825	-
MgO	.854	-.356	-
Eigen vales	2.872	1.048	0.567
Percentage of variance	57.448	20.964	11.345
Cummulative percentage	57.448	78.412	89.757

Table 4: Descriptive statistics of trace elements of soils and sediments of the study area

NO	Description	Cu	Pb	Zn	As	Cd	Ba
S1	Eyin Grammar	137	2333	992	3	2.6	240
S2	Eyin Grammar	34.5	79	211	2	0.5	102
S3	Owode Academy	16	36	198	2.5	0.5	70
S4	Owode	21.5	41.5	197	2	0.5	67
S5	Surulere	57	170.5	906	2.5	0.8	101
S6	Laoye Muslim	45.5	74.5	912	2	2.1	107
S7	Kudeti	37	90.5	312	3	0.7	147
S8	Odinjo	83.5	127	2716	3.5	2.2	145
S9	Olorunsogo	20.5	53	493	2	0.5	72
	mean	50.28	333.89	770.78	2.50	1.16	116.78
	Stan dev	38.74	750.88	800.73	0.56	0.87	54.92
	Range	16-137	36-2333	197-2716	2-3.5	0.5-2.6	67-240
SS10	Ogunpa River	46	78	267	2	0.5	77
SS11	Ogunpa River	75	82	657	2	0.5	217
SS12	Elere River	77	99	285	2	0.5	81
SS13	Elere River	121	114	307	2	0.5	88
	mean	79.75	93.25	379.00	2.00	0.50	115.75
	starndev	30.93	16.56	186.05	0.00	0.00	67.65
	Range	46-121	78-114	267-657	02-Feb	0.5-0.5	77-217
	Crustal Average	50	12.5	97.9	1.8	0.2	500

Table 5: Correlation Coefficient of trace elements for the soil and stream sediment

	Cu	Pb	Zn	As	Cd	Ba
Cu	1					
Pb	**.643(*)**	1				
Zn	.355	.177	1			
As	.292	.401	**.707(**)**	1		
Cd	.497	**.645(*)**	**.724(**)**	**.612(*)**	1	
Ba	**.604(*)**	**.672(*)**	.388	.477	**.559(*)**	1

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Index of Geo-Accmulation for soil and stream sediment

Geo-accumulation classification index (I_{geo}) for soil (Table 7) revealed Ba (-2.7), Cu (-0.6) and As (-0.11) with lgeo <0 (practically uncontaminated), Cd (1.93) and Zn (2.4) (moderately contaminated), and Pb with the highest Igeo of 4.75 indicating high to very high contamination. The geo-accumulation classification index (I_{geo}) for stream sediment revealed practically uncontaminated Ba (-2.7), As (-0.4), Cu (0.1) and Cd (0.7); and moderately contaminated Zn (1.4) and Pb (2.3) in all the elements (Fig. 6). Possible sources of Pb may include leaded gasoline, tyre wears and automobile emissions, batteries and municipal waste effluents/sewage sludge. Excessive concentration of the element in areas can cause lung cancer in human.

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Table 6: Anthropogenic Factor of the trace elements in Soil and Stream sediments

Elements	**Cu**	**Pb**	**As**	**Cd**	**Ba**	**Zn**
S_1	2.7	186.6	1.7	13	0.5	10.1
S_2	0.7	6.3	1.1	2.5	0.2	2.2
S_3	0.3	2.9	1.4	2.5	0.1	2.0
S_4	0.4	3.3	1.1	2.5	0.1	2.0
S_5	1.1	13.6	1.4	4.0	0.2	9.3
S_6	0.9	6.0	1.1	10.3	0.2	9.3
S_7	0.7	7.2	1.7	3.3	0.3	3.2
S_8	1.7	10.2	1.9	1.1	0.3	27.7
S_9	0.4	4.2	1.1	2.5	0.1	5.0
SS10	0.9	6.2	1.1	2.5	0.2	2.7
SS11	1.5	6.6	1.1	2.5	0.4	6.7
SS12	1.5	7.9	1.1	2.5	0.2	2.9
SS13	2.4	9.1	1.1	2.5	0.2	3.2

Table 7: Geo-accumulation index (I_{geo}) of the trace elements in soil and steram sediment

Elements	**Cu**	**Pb**	**As**	**Cd**	**Ba**	**Zn**
S_1	0.8	7.2	0.2	3.1	-1.6	2.8
S_2	-1.1	2.1	-0.4	0.7	-2.9	0.5
S_3	-2.3	0.9	-0.1	0.7	-3.4	0.4
S_4	-1.8	1.2	-0.4	0.7	-3.5	0.4
S_5	-0.3	3.2	-0.1	1.4	-2.9	2.6
S_6	-0.6	1.9	-0.4	2.8	-2.8	2.6
S_7	-1.0	2.3	0.2	0.3	0.3	1.1
S_8	0.2	2.8	0.4	2.9	2.9	4.2
S_9	-1.9	1.5	-0.4	0.7	0.7	1.7
SS_{10}	-0.7	2.1	-0.4	0.7	-3.3	0.9
SS_{11}	0	2.1	-0.4	0.7	-1.8	2.2
SS_{12}	0.1	2.4	-0.4	0.7	-3.2	1.0
SS_{13}	0.7	2.6	-0.4	0.7	-3.1	1.1

Quantification of Degree of Pollution

In table 8a&b, the degree of pollution of the soils revealed high anthropogenic contribution of Pb (62.2%), Zn, Cd, As, Cu and Ba with 18.4%, 13.3%, 3.3%, 2.3% and 0.47% respectively. The summation of the respective single metal contamination indices shows a contamination degree (Cdeg) of 42.9 similar contamination degree (Cdeg) of >32 (Hakanson, 1980) associated with high metal contamination within the study area. In stream sediments high anthropogenic contribution of the elements include Pb, Zn, Cd, Cu, As, and Ba with 44.6%, 23.2%, 14.9%, 9.5%, 6.6% and 1.2% respectively (see fig.7). The respective single metal contamination indices revealed considerable degree of metal contamination in the study area (Hakanson, 1980). Therefore, the order of degree of anthropogenic factor contamination or enrichment in both soil and stream sediments is Pb>Zn>Cd>Cu>As>Ba.

Table 8a: Summary of quantitative indices with respect to metal contamination in soil samples

Trace elements	**A.F**		**I_{geo}**		**Summary of overall contamination level**
	RANGE	**MEAN**	**RANGE**	**MEAN**	
Cu	0.32-2.74	1.0	-2.3-0.8	-0.6	*Very low/No contamination*
Ba	0.13-0.48	0.2	-3.4 to -1.6	0.16	*Very low/no contamination*
As	1.1-1.9	1.4	-0.4-0.4	-0.11	*Very low/no contamination*
Cd	2.5-13	5.7	0.7-3.1	1.93	*Moderate to high contamination*
Zn	2.02-10.13	7.9	0.4-4.2	2.40	*Moderate to heavily contamination*
Pb	2.88-186.6	26.7	0.9- 7.2	4.75	*Heavily contaminated*

A.F=Anthropogenic Factor *Igeo=Index of geoaccumulation*

Table 8b: Summary of quantitative indices with respect to metal contamination in stream sediments

Trace elements	**A.F**		**I_{geo}**		**Summary of overall contamination level**
	RANGE	**MEAN**	**RANGE**	**MEAN**	
Cu	0.92-2.42	1.60	-0.71-0.69	0.1	*Very low/no contamination*
Ba	0.15-0.4	0.23	-3.3 -1.8	-2.71	*No contamination*
As	1.1-1.1	1.0	-0.4 --0.4	-0.4	*No contamination*
Cd	2.5-2.5	2.5	0.7-0.7	0.74	*Very low contamination*
Zn	2.73-6.71	3.9	0.9-2.17	1.4	*Moderate contamination*
Pb	0.24-9.12	7.5	2.1- 2.61	2.3	*Moderate to high Contamination*

A.F=Anthropogenic Factor *Igeo=Index of geoaccumulation*

Risk Index

The risk index of soil is shown in table 9; Ba, As and Cu are within the permissible index of ko <1, Cu is medium dangerous with Ko of 1-3, Cd and Zn are dangerous and Pb is extremely dangerous with ko > 10. Similarly, Zn (3.9) and Pb (7.5) dangerous in stream sediment though with values are lower than the soil.

Quantitative indices with respect to metal contamination in soil and sediment phase (Table 9& 10) revealed the trend of anthropogenic contamination to be consistent with the estimated index of geo-accumulation values and anthropogenic factor, though higher in soils than sediment samples. Environmental contamination arouse from urban degradation triggered by improper land-use plans, poor sanitary and waste/sewage disposal facilities, and inadequate public awareness of environmental health issues. This had resulted into systematic degradation of the environment in Ibadan metropolis. Notable aspect of this degradation that is of serious health concern is the contamination of ground water and drainage by the heavy metals.

Table 9: Risk index (K_o) for trace elements in soil and stream sediment.

Elements	**Cu**	**Pb**	**As**	**Cd**	**Ba**	**Zn**
S_1	2.8	186.6	1.7	13	0.5	10.1
S_2	0.7	6.3	1.1	2.5	0.2	2.2
S_3	0.3	2.9	1.4	2.5	0.1	2.0
S_4	0.4	3.3	1.1	2.5	0.1	2.0
S_5	1.1	13.6	1.4	4.0	0.2	9.3
S_6	0.9	6.0	1.1	10.3	0.2	9.3
S_7	0.7	7.2	1.7	3.3	0.3	3.2
S_8	1.7	10.2	1.9	1.1	0.3	27.7
S_9	0.4	4.2	1.1	2.5	0.1	5.0
SS_{10}	0.9	6.2	1.1	2.5	0.2	2.7
SS_{11}	1.5	6.6	1.1	2.5	0.4	6.7
SS_{12}	1.5	7.9	1.1	2.5	0.2	2.9
SS_{13}	2.4	9.1	1.1	2.5	0.2	3.2

Conclusion

The result showed effect of urbanization coupled with poor sanitization that occurs in many cites in the study area. The dominance of Fe_2O_3 in the sediments when compared with the soil confirmed poor sanitary and waste/sewage disposal facilities in the study area where there stream channel is used majorly as the waste disposal tank, high pollution of Pb, Zn, Cd found in the study area could also be attributed to anthropogenic impacts that could be from vehicular emission, related repair products, domestic sewages, market and industrial effluents.

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