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Contamination Assessment of Trace Metal in Soil and Stream sediments of Ibadan and its Environs, Southwestern Nigeria

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Abstract

High porous nature of soil makes it susceptible to influx of heavy metals that comes from anthropogenic activity. Contamination assessment of heavy metals in soil and sediments was conducted in Ibadan southwestern Nigeria. Samples were randomly collected, sieved and, analysed. Iron (III) oxide (Fe_2O_3) was found to be dominant in the soil and stream sediment of the study area. A decreasing order of metals Zn>Pb>Ba>Cu>As>Cd was observed from the soil and stream sediment. Pollution of Zn and Pb in both soil and stream sediments were confirmed by anthropogenic enrichment [soil - Zn (7.9) and Pb (26.7; stream sediment - Zn (3.9) and Pb (7.5)], Index of geoaccumulaton [soil- Zn (2.4) and Pb (4.75); stream sediment Zn (1.4) and Pb (2.3)]. High occurrence of Zn and Pb observed in the study area revealed the influence of anthropogenic activity such as battery making, indiscriminate dumping of refuse and use of leaded paint washed and discarded on the soil that gets leached into the stream sediment of the environment. A well monitored disposal tank must be placed in a central place for people to use by the government and a law enforcement agent should be placed at a strategic position to enforce the law of sanitation.

Évaluation de la contamination par les métaux traces dans le sol et les sédiments fluviatiles d'Ibadan et de ses environs, sud-ouest du Nigéria

Abstrait

La nature hautement poreuse du sol le rend vulnérable à l'afflux de métaux lourds provenant d'activités anthropiques. Une évaluation de la contamination des métaux lourds dans le sol et les sédiments a été réalisée à Ibadan, dans le sud-ouest du Nigéria. Les échantillons ont été prélevés au hasard, tamisés et analysés. L'oxyde de fer (III) (Fe2O3) s'est révélé dominant dans les sols et les sédiments de ruisseau de la zone d'étude. Un ordre décroissant des métaux Zn> Pb> Ba> Cu> As> Cd a été observé dans le sol et les sédiments de ruisseau. La pollution de Zn et de Pb dans le sol et les sédiments de ruisseau a été confirmée par l'enrichissement anthropique [sol - Zn (7,9) et Pb (26,7; sédiment de ruisseau - Zn (3,9) et Pb (7,5)], indice de géoaccumulaton [sol - Zn (2,4) et Pb (4,75); Zn (1,4) et Pb (2,3)] dans les sédiments de ruisseau. La forte présence de Zn et de Pb observée dans la zone d'étude a révélé l'influence d'activités anthropiques telles que la fabrication de batteries, le déversement aveugle de déchets et l'utilisation de déchets. peinture au plomb lavée et jetée sur le sol qui est lessivé dans les sédiments de la rivière.Un réservoir de stockage bien surveillé doit être placé dans un endroit central à la disposition du public, et un agent de la force publique devrait être placé à un emplacement stratégique pour. faire respecter la loi de l'assainissement la sanitation.

Introduction

Soils are produced from the breakdown of pre-existing rocks of Precambrian Basement Complex; they are formed from biological, climatic, geological and topographical activities and consist of porous medium that accommodates minerals, water, air, organic matter, and countless organisms from decaying remains of once-living things. Soils are therefore known as complex mixtures which can be transported from one place to another by different media such as wind, water, ice, gravity (Garrison, 2019).

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 and Velbel, 2003, Sharma and Rajamani 2003, Garrison, 2019); these factors will be responsible for the chemistry of loose sediment.

Due to the porous nature of soil it makes the top soil prone to high environmental degradation that occurs from anthropogenic activities which culminates from contaminants of surface drainage systems that are mostly related to the consequences of population growth, urbanization, agricultural activities and development of new industrial zones (Price and Velbel, 2003). Other types of anthropogenic activity that are critical components of heavy metals emission which subsequently leads to contamination into the soils are uncontrolled direct dumping of domestic wastes and discharge of domestic and industrial sewage into the urban drainage systems, inadequate land use planning and improper waste disposal and management systems.

The heavy metals released could be major, trace or even rare metals. However, the release of trace metals associated with such geo-pedological soil processes could have both positive and negative impacts on the environment (Tijani *et al.,* 2005).

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 degradation and subsequent health problems (Cobelo-Garcia *et al.,* 2003).

Trace metal contaminated soil and sediments therefore, represent 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 (Farid, *et al.,* 2015; Yang *et al.,* 2018). The metal has harmful effects on both human and environment, even at low concentration (Nriagu, 1994; Chowdhury, 2000; Chwirka *et al.,* 2000; Dogan, 2000; DeMarco *et al.,* 2003; Wasserman, *et al.,* 2004).

Uncontrolled rate of population in Nigeria, due to rural –urban migration in the last few decades, characterizes most of the big cites and urban centres. Unfortunately, poor sanitary and wastes/sewage disposal facility had led to gradual degradation of the environment (Tijani *et al.,* 2004).

Ibadan, a major city found in the southwestern part of Nigeria is greatly affected by this degradation (Figure 1) basically due to uncontrolled human activities in the city. The study therefore focused on the contamination of heavy metals and its effect on public health on the environment of Ibadan metropolis.

Figure 1: Environmental degradation in a typical major market in Ibadan

Materials and Methods

Study Location

Ibadan, the study area found in the South-western part of Nigeria is the largest indigenous city in sub-Sahara Africa with an estimated population of one hundred and seventy-five thousand in 1911.

The population of Oyo state where Ibadan is located has increased from over six million to over seven million between 2012 and 2016 (NBS, 2017). The population of central Ibadan the study area, is three million one hundred and sixty thousand two hundred (3,160,200) as at 2015 (Ibadan Population, 2015) covering an area of 128 km^2.

However, the growth of the city has nothing to do with industrialization (with only few industries) , rather it is related to the age long role of the city as regional administrative capital since the colonial era. The city is thus characterized by lack of proper sewage and waste disposal systems (Figure 1).

The implication of these problems is that many households especially within the congested central part of the city (which constitute the core of the study), lack toilet and waste disposal facilities (Tijani, and Ayodeji, 2002; Tijani, *et al.,* 2004; 2007; Tijani, and Agakwu, 2007). Such households therefore, defecate and pour their wastes directly into water bodies thereby reducing the quality of soil and water found in the area.

The main activity observed in the study area revealed a mini-industry of soap making, plastic factory, battery making, steel and iron work industries, this leads to the concentration of sewage sludge found in the river within the study area.

Location and Accessibility

Ibadan, located in the South-west of Nigeria, lies between latitude $7^{0}15'$N – $7^{0}30'$N and longitude $3^{0}45'$E – $4^{0}00'$E, the city is 78 miles inland from Lagos; 128 km inland northeast of Lagos and 530 km southwest of Abuja, it is a prominent transit point between the coastal region and the areas to the north.

The location of soil and sediment study is situated on latitude $7^{0}22'$N and Longitude $3^{0}56'$E, parts of the core area of the city, characterized by poor sanitary and waste/sewage disposal facilities being used as their stream channel.

Ibadan has major and minor roads which makes it easily accessible to adjoining towns and cities of other states.

Sampling and study design

Nine top soils were sampled from levels 0 – 5 cm, the samples were put in a properly labelled cellophane bag from the field to avoid distortion of samples. Four stream sediment samples were also packed into a well labelled cellophane bag from the field, the samples were allowed to drain and immediately bagged. The soil and stream sediments were both bagged to avoid contamination.

The samples were then air dried for about fourteen (14) days at room temperature to reduce the rate of fungi growth contamination especially on the sediments.

The samples were sieved with the layered sieving can and the least size sieve of 63µm was finally used for the samples.

Soil and stream sediment samples sieved were finally packaged for analysis using the inductive coupled plasma mass spectrometry (ICP-MS) method.

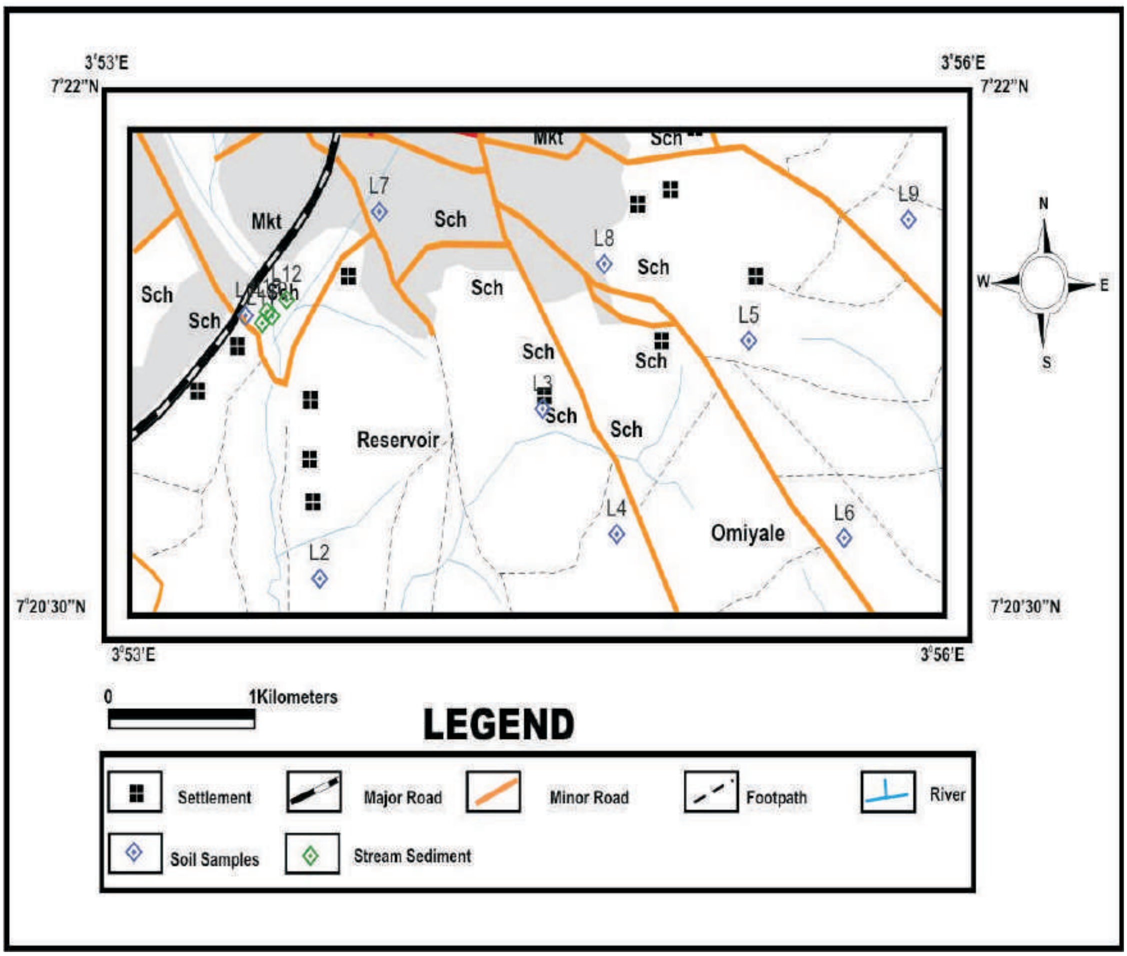


Figure 2: Sampling points in the study area

Results

Trace element result for soil and stream sediment

Mean concentrations for all the elements in both soil and stream sediment showed a decreasing order as follows: Zn>Pb>Cu>As>Cd, but the concentration of trace elements in soil samples is quite higher than that of stream sediments in the areas.

A strong and positive correlation (Table 2) was observed amongst the metals Cu-Pb (0.6), Cu-Ba (0.6), As-Zn (0.7), Cd-As (0.6), Zn-Cd (0.7) in the inter-elemental relationship between soil and stream sediment.

Table 1: Trace metal concentration of soil and stream sediment in the study area

a. Soil

No.	Location	Cu	Pb	Zn	As	Cd	Ba
S1	Eyin Grammar	137	2333	992	3	2.6	240
S2	Eyin Grammar Owode	34.5	79	211	2	0.5	102
S3	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

b. Stream sediment

No.	Location	Cu	Pb	Zn	As	Cd	Ba
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
	Starn Dev	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 2: Inter-Elemental Relationship between trace elements in soil and stream sediment

	Cu	Pb	Zn	As	Cd	Ba
Cu	1					
Pb	**0.643(*)**	1				
Zn	0.355	0.177	1			
As	0.292	0.401	**0.707(**)**	1		
Cd	0.497	**0.645(*)**	**0.724(**)**	**0.612(*)**	1	
Ba	**0.604(*)**	**0.672(*)**	0.388	0.477	**0.559(*)**	1

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

Statistical Evaluation for Level of Contamination in the Soil and Stream Sediment

Anthropogenic Factor (A.F) and Index of Geoaccumulation (I_{geo}) was used in the study to evaluate the level of contamination in the various media.

The anthropogenic factor for soil and stream sediment (Table 3) revealed low contamination in all the metals with the exception of Zn and Pb in both media which had a high concentration [soil - Zn (7.9) and Pb (26.7; stream sediment - Zn (3.9) and Pb (7.5)]. A similar result was also observed in the geo-accumulation classification index (I_{geo}) (Table 4) where Cd (1.93) and Zn (2.4) were moderately contaminated; and Pb (4.75) was highly to very highly contaminated in soil, while the stream sediment was moderately contaminated with Zn (1.4) and Pb (2.3) (Figures 3a & b).

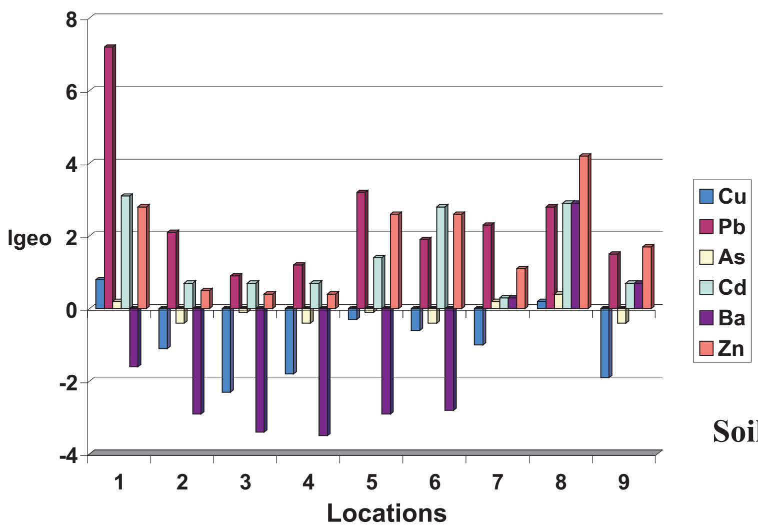
Possible source of Pb emission in abundance in the study area could be from leaded gasoline and tyre wears. Automobile emissions, batteries and municipal waste effluents/sewage sludge found within the study area; Pb has been found to cause Lung cancer if it is in excess (Jesperson, 2004).

Table 3: Anthropogenic factor of the Trace metals in Soil (S) and Stream Sediments (SS)

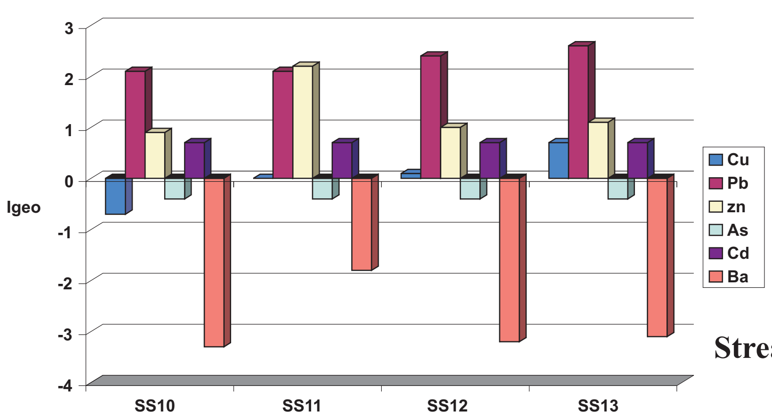
Elements	**Cu**	**Pb**	**As**	**Cd**	**Ba**	**Zn**
S_1	2.7	186.6	1.7	13	0.5	10.1
S_2	0.7	6.3	1.1	2.5	0.2	2.2
S_3	0.3	2.9	1.4	2.5	0.1	2.0
S_4	0.4	3.3	1.1	2.5	0.1	2.0
S_5	1.1	13.6	1.4	4.0	0.2	9.3
S_6	0.9	6.0	1.1	10.3	0.2	9.3
S_7	0.7	7.2	1.7	3.3	0.3	3.2
S_8	1.7	10.2	1.9	1.1	0.3	27.7
S_9	0.4	4.2	1.1	2.5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

Table 4: Geo-accumulation index (I_{geo}) of the Trace metals in soil and stream sediments

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



Soil samples (a)



Stream sediments (b)

Figures 3 a & b: Igeo concentrations of trace elements for the samples

Discussion

The highest concentration of metals was found in Elere River (LC13), Eyin Grammar (LC1) and Surulere (LC5) due to sewage sludge, steel and iron works and refuse incineration activities found within the area. These metals when compared with their respective crustal average according to Tijani *et al.,* (2005) are higher than the recommended average with the exception of barium (Ba), (Table 1). Since the samples taken are from densely populated areas, these revealed that all the metals were from human activities through the different mini - industries such as soap making factory, plastic factory, battery making industry, steel and iron work industries.

The strong and positive correlation result observed from the inter-elemental relationship between soil and stream sediment confirmed that the metals found in the media were from the same anthropogenic source.

Conclusion

The study assessed the impact of contamination through diverse anthropogenic activities that exists in the study area, due to urbanization. High contamination of metals such as Pb Zn and Cd was observed in soil and stream sediments of the study area which could be attributed to exhaust of vehicles and careless use and disbandment of batteries and leaded paints. The dominance of iron III oxide (Fe_2O_3) in the sediments when compared with the soil also influenced anthropogenic activity which indicates poor sanitary, market and industrial effluents and waste/sewage disposal facilities. The result also showed that the stream channel was used mainly as waste disposal tank in the study area. It is therefore eminent for the government to place a disposal tank in the area which can help the inhabitants of the community with their waste disposal. A law enforcement agent must secure the area where the disposal tank is to enforce the proper disposal of waste into the tank. Health workers must be equipped and enforced to move through the community and also monitor industrial wastes, so as to prevent the contamination of the area.

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