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Assessment of Toxic Elements (TEs) in Freshwater Surficial Sediments: Case Study of Kuto – Ijeun Titun Streams, Abeokuta, Ogun State, Nigeria

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ABSTRACT

Toxic elements (TEs) found in surficial sediments from water bodies in Nigeria have consistently led to high levels of pollution attributed to human activities, such as population growth, agricultural practices, and industrialization. This study aimed to assess the presence and level of TEs in selected stream sediments within Kuto–Ijeun Titun, Abeokuta, Ogun State, Nigeria. Ten surficial sediment samples were strategically collected from upstream and downstream of five streams, air-dried, and acid-digested. An Atomic Absorption Spectrophotometer (AAS) was used to analyze the TEs in the sediment samples. The results indicated that the mean Cadmium (Cd), Iron (Fe), and Lead (Pb) across all sampling stations exceeded the European Union (EU) standards, measuring 5.74, 7312.72, and 529.84 mg/kg

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respectively. In contrast, Cobalt (Co), Chromium (Cr), Copper (Cu), Manganese (Mn), and Zinc (Zn) levels were within the EU standards, measuring 1.53, 32.84, 27.96, 47.62, and 18.85 mg/kg respectively. Correlation at $p < 0.05$ showed a positive moderate correlation between Cd-Mn (r = 0.436), and Cr-Fe (r = 0.462). Negative moderate correlation between Cd-Co (r = -0.550), Fe-Pb (r = -0.535), Pb-Zn (r = -0.610) and a significantly strong correction between Co-Mn (r = -0.710). Factor analysis revealed four components totalling 86.4% of the variance and moderate loadings with Cd and Mn, Fe and Zn, and strong loadings from Cr and Cu. The presence of some of these TEs potentially poses a significant environmental pollution threat to the community. Therefore, urgent actions should be taken to mitigate and remediate the study streams of these toxic elements.

***Keywords*:** Abeokuta, Kuto-Ijeun, Sediments, Streams, Toxic elements

1. INTRODUCTION

Sediments play a significant role in our environment, acting as reservoirs for harmful chemical substances that stem from human waste discharged into water bodies (Osakwe and Peretiemo-Clarke, 2013). These sediments not only preserve essential environmental data but are also increasingly acknowledged for their dual role as carriers and potential sources of pollutants in aquatic ecosystems (Osakwe and Peretiemo-Clarke, 2013; Famuyiwa *et al*., 2023).

In these vibrant ecosystems, sediments are vital for the development, growth, and establishment of various aquatic organisms, providing a foundation where life can thrive. Moreover, they serve as a repository for a wide range of pollutants, capturing toxic materials and preventing their widespread distribution. The ability of sediments to act as a sink for pollutants stems from an intricate interplay of factors, including river hydrodynamics, biogeochemical processes, and specific environmental conditions (Enuneku *et al*., 2017; Famuyiwa *et al*., 2025). This complex web of interactions illustrates the critical importance of sediments in maintaining the health and balance of aquatic ecosystems.

Metals found in soil solutions, surface waters, and interstitial waters, as well as those that become adsorbed to sediments through cation exchange processes, tend to be readily accessible to a variety of aquatic and benthic organisms, as well as to plants (Ladigbolu and Balogun, 2011; Malik *et al*., 2024). The problem of metal pollution stemming from toxic elements (TEs) is alarming due to their inherently harmful properties and their potential for bioaccumulation, which poses significant risks not only to the environment but also to human health (Famuyiwa *et al*., 2013; 2025). The chemical characteristics of sediments play a crucial role in determining the mobility, bioavailability, and resultant toxicity of these toxic elements, underscoring the importance of element speciation as a vital area of scientific inquiry (Salniko *et al*., 2013).

Toxic elements, or TEs, are defined as those elements possessing a density greater than 5-6 g/cm^3 (Famuyiwa *et al*., 2025). They are categorized into two distinct groups: essential elements that are vital for certain biological processes in organisms - such as arsenic (As), chromium (Cr), copper (Cu), nickel (Ni), and zinc (Zn) - and non-essential elements that have no known biological role, which include mercury (Hg), lead (Pb), and cadmium (Cd) (Famuyiwa *et al*., 2013; 2025; Aluko *et al*., 2024). Extensive research has revealed that many water bodies and sources throughout Nigeria are experiencing pollution from a range of toxic elements (TEs) at varying concentrations (Uwah *et al*., 2013; Famuyiwa *et al*., 2013; Umoren *et al*., 2014a, b, c; Famuyiwa *et al*., 2025; Aluko *et al*., 2024; Akinbola *et al*., 2025).

Moreover, these toxic elements can travel significant distances - sometimes hundreds of kilometres - downriver from their sources of emission, particularly in rivers that exhibit high discharge flows, frequent flooding events, and relatively flat sediment profiles (Morgan, 2013).

The presence of high levels of trace elements (TEs) in aquatic environments poses a serious environmental challenge due to their potentially harmful effects and their resistance to natural decomposition (Ephraim and Ajayi, 2015). While trace elements like copper, selenium, and zinc play essential roles in human nutrition at low concentrations, they can become detrimental at elevated levels. Moreover, other elements such as lead, chromium, arsenic, and mercury lack any known biological function and are considered particularly hazardous (Famuyiwa *et al*., 2013).

In recent decades, urban expansion has significantly increased the reliance on various anthropogenic sources emitting these trace elements, leading to widespread contamination. Research has shown that exposure to TEs over an extended period can inflict a range of severe health consequences. For instance, lead exposure has been linked to severe cognitive deficits, harm to the nervous system and kidneys, impairments in learning, difficulties in muscle coordination, reduction in hearing ability, elevated blood pressure, and inhibited growth in both muscles and bones. Similarly, exposure to chromium has been associated with an increased risk of cancer (Olujimi *et al*., 2015).

In Nigeria, there has been a surge in investigations focused on the contamination of trace elements in stream sediments, reflecting growing environmental concerns (Aderinola *et al*., 2009; Chindah *et al*., 2009; Olubunmi and Olorunsola, 2010; Ladigbolu and Balogun, 2011; Majolagbe *et al*., 2012; Butu and Iguisi, 2013; Uwah *et al*., 2013). The present study seeks to meticulously assess and evaluate the concentrations of toxic elements found in the sediments of selected streams within the Kuto–Ijeun Titun Community, situated in Abeokuta, Ogun State, Nigeria. This research is crucial in understanding the environmental impact and potential health risks associated with these contaminants in the region.

2. MATERIALS AND METHODS

2. 1. Study Area

The study was carried out across stream sediments in the vicinity of kuto and Ijeun Titun communities in Abeokuta, Ogun state, Nigeria. Abeokuta is a city located between latitude 7° 20’ north of the equator and between longitude 3°20’ east of the Greenwich Meridian. The city experiences the wet and dry seasons. The wet season runs from April through October while the dry season runs from November through March. The main rock type found in the study area is older granite rock which has undergone intense weathering into a reddish to dark brown medium-grained lateritic layer of considerable thickness. The streams in the city are used by some of its residents as potable water and domestic activities (Umoren *et al*., 2024b, c). The streams around the study areas and their coordinates are presented in Table 1, the study was carried out in July- August 2024.

2. 2. Sediment Collection and Processing

Exactly, ten (10) sediment samples were strategically collected from five streams located in the Kuto - Ijeun Titun community. The collection was conducted both upstream and downstream, ensuring a thorough representation of the sediment characteristics in the area.

Using a sturdy shovel, the researchers gathered the sediments, allowing them to drain naturally before transferring the collected materials into durable polythene sampling bags. These bags safely housed the samples as they were transported to the chemistry laboratory for further examination. Upon arrival at the laboratory, the sediments were spread out and left to air dry for a full week, allowing moisture to evaporate and preparing them for subsequent processing. After the drying period, the sediments were carefully sieved using a 1000 μm mesh to eliminate dirt and larger particles that could interfere with analysis. This meticulous cleaning process ensured that only the finest materials were retained, which were then stored in preparation for the digestion processes that would follow.

Table 1. Description of sampled sediment and geographical coordinates

Sample ID	Streams	Geo-coordinate
Station A	Ijeun- Titun	7°08'47.2"N 3°21'24.1"E
Station B	Isabo	7°08'36.9"N 3°20'55.4"E
Station C	Isale- Oja Kuto	7°08'38.0"N 3°21'13.1"E
Station D	Lafaru	7°08'15.4"N 3°21'19.8"E
Station E	Stadium	7°08'00.9"N 3°21'25.1"E

Field survey 2024

2. 3. Sediment Digestion and TE Analysis

The digestion process was carried out using the *Aqua-regia* method, a technique renowned for its effectiveness in breaking down complex matrices. To begin, one gram of each sediment sample was carefully weighed and placed into a flask containing a carefully prepared mixture of nitric acid (HNO_3) and hydrochloric acid (HCl) in a precise ratio of 1:3. This combination of acids is powerful, allowing for the thorough dissolution of metal compounds within the sediment.

The mixture was then gently stirred to ensure the formation of a homogeneous solution, enabling the acids to penetrate and react with the sample effectively.

To facilitate the digestion, the flask was placed in a fume cupboard where it was subjected to controlled heating. This step was crucial, as it allowed the volume of the solution to reduce from its initial 25 mL down to approximately 15 mL, concentrating the analytes of interest. Once the solution cooled to room temperature, the resultant liquid was filtered to remove any undissolved particles or impurities. Following filtration, the concentrated solution was diluted with distilled water to achieve a final total volume of 50 mL.

This dilution was necessary to prepare the sample for subsequent analysis. The diluted samples were then subjected to analysis using an Atomic Absorption Spectrophotometer (AAS), a sophisticated instrument designed to detect trace elements with high sensitivity. The AAS was utilized to quantify the presence and concentrations of the trace elements (Famuyiwa *et al.*, 2022; Umoren *et al*., 2024d).

2. 4. Data Management and Analysis

Collected data were analyzed, and were calculated using Microsoft Excel, 2013. Results were represented in tables and charts.

3. RESULTS AND DISCUSSION

3. 1. Concentration of TEs in Selected Stream Sediments

The results are shown below. At station A, cadmium (Cd) levels ranged from 2.18 mg/kg to 9.55 mg/kg. The lowest level was found downstream of station C, while the highest was downstream of station E. The average Cd level across all stations A-E was 5.74 mg/kg, which is higher than the European Union (EU) standard of 0.3 mg/kg. Cadmium is a toxic heavy metal that can harm human health, particularly affecting the kidneys. If Cd builds up in the kidneys over time, it can damage kidney function and also impact the liver, immune system, and blood vessels (Atarug *et al*., 2010).

Cobalt (Co) levels ranged from 0.56 mg/kg to 2.86 mg/kg. The lowest level was upstream of station C, and the highest was downstream of station A. The average Co level across all stations A-E was below the EU standard of 140 mg/kg. Cobalt in sediment can come from natural sources or human activities, such as using phosphate-based fertilizers, smelting, sewage sludge, alloys, and mining. In water, cobalt tends to settle in the bottom sediment or attach to suspended particles (ATSDR).

Chromium (Cr) levels ranged from 18.24 mg/kg to 45.25 mg/kg. The lowest level was found downstream of station B, while the highest was upstream of station A. The average Cr level across all stations A-E was within the EU standard of 180 mg/kg. Chromium exists in two forms: trivalent (Cr3+) and hexavalent (Cr^{6+}), with Cr^{6+} being the most toxic (Famuyiwa *et al*., 2021). Chromium levels in the sampled soil were lower than the UK standard of 200 mg/kg and the DIV standard of 380 mg/kg, and also lower than levels found in topsoil studies in Accra, Ghana (96.7 mg/kg) (Sam *et al*., 2015).

Copper (Cu) levels ranged from 12.36 mg/kg to 45.25 mg/kg. The lowest level was upstream of station E, and the highest was downstream of station E. The average Cu level across all stations A-E was above the EU standard of 140 mg/kg. Copper is essential for various body functions, but too much can cause health issues like diarrhoea, vomiting, liver damage, nausea, and abdominal pain (Ulla *et al*., 2012). This level is higher than findings from soil studies in Lagos, Nigeria (8.0 mg/kg) (Famuyiwa *et al*., 2018).

Iron (Fe) levels ranged from 4457.567 mg/kg to 10545.36 mg/kg. The lowest value was downstream of station C, while the highest was upstream of station A. The average Fe level across all stations A-E was above the EU standard of 1500 mg/kg. Zinc (Zn) mostly comes from natural sources, but human activities like steel manufacturing and galvanization also contribute (Olujimi *et al*., 2015). The average Zn level was lower than reports from soil studies in Accra, Ghana (343 mg/kg) (Lawal *et al*., 2015).

Manganese (Mn) levels ranged from 28.36 mg/kg to 69.35 mg/kg. The lowest level was downstream of station C, while the highest was upstream of station E. The average Mn level across all stations A-E was within the EU standard of 200 mg/kg. Manganese is essential for health, but high exposure can lead to serious health effects, such as respiratory problems and neurological disorders (Iwegbue *et al*., 2019). The average Mn level is higher than reports from soil studies in Lagos, Nigeria (132 mg/kg) (Famuyiwa *et al*., 2018).

Lead (Pb) levels ranged from 265.41 mg/kg to 882.419 mg/kg. The lowest level was downstream of station E, while the highest was upstream of station B. The average Pb level across all stations A-E was above the EU standard of 400 mg/kg. The United States Environmental Protection Agency states that lead can be harmful to most living things (USEPA, 2015). The average Pb concentration was higher than the findings from Lagos, Nigeria (17 mg/kg) (Famuyiwa *et al.*, 2018).

The concentrations of zinc (Zn) ranged from 15.70 mg/kg to 24.59 mg/kg. The lowest concentration was recorded downstream at station D, while the highest concentration was found upstream at station E. The average zinc level across all stations (A-E) complied with the European Union (EU) standard of 300 mg/kg. Zinc is primarily a geogenic element, and its release into the environment mainly results from human activities, such as steel production and zinc galvanization.

Table 2. Toxic Elements Level (mg/kg) in Sediments

Stations	Points	Cd	Co	Cr	Cu	Fe	Mn	Pb	Zn
Station A	Up Stream	4.89	1.768	45.254	36.21	10545.36	56.245	748.545	17.965
	Down Stream	3.65	2.858	23.412	22.56	9564.251	48.265	692.414	21.542
Station B	Up Stream	4.25	1.228	22.626	23.65	6582.415	36.187	882.419	19.456
	Down Stream	6.24	1.069	18.242	19.65	8569.455	29.335	695.215	17.254
Station C	Up Stream	5.54	0.563	19.248	35.98	6589.245	47.298	478.266	16.512
	Down Stream	2.184	0.695	44.62	32.851	4457.569	28.365	542.63	18.654
Station D	Up Stream	6.235	1.141	42.65	24.591	6988.621	57.265	302.14	19.541
	Down Stream	9.245	1.542	39.24	26.447	6965.652	55.632	406.25	24.586
Station E	Up Stream	5.627	2.264	33.65	12.364	7584.699	69.354	285.11	15.699
	Down Stream	9.548	2.145	39.47	45.251	5279.895	48.264	265.41	17.254
Average		**5.74**	**1.53**	**32.84**	**27.96**	**7312.72**	**47.62**	**529.84**	**18.85**
Std. Dev.		**2.29**	**0.73**	**10.88**	**9.60**	**1848.10**	**13.08**	**217.48**	**2.68**
Minimum		**2.18**	**0.56**	**18.24**	**12.36**	**4457.57**	**28.37**	**265.41**	**15.70**
Maximum		**9.55**	**2.86**	**45.25**	**45.25**	**10545.36**	**69.36**	**882.42**	**24.59**
European Union (EU) Standard		**3.00**	**140.00**	**180.00**	**140.00**	**1500.00**	**200.00**	**400.00**	**300.00**

3. 2. Correlation Matrix

The association between TEs can provide useful insight into the sources of element into the water body (Famuyiwa *et al*., 2021). The relationship between TEs at $p < 0.05$ is presented in Table 3, which reveals a positive moderate correlation between Cd-Mn (r = 0.436), and Cr-Fe (r = 0.462). furthermore, there is a negative moderate correlation between Cd-Co (r = -0.550), Fe-Pb (r = -0.535), Pb-Zn (r = -0.610) and a significantly strong correction between Co-Mn (r = -0.710). The TEs that are considerably connected predict likely similar sources. However, the moderate correlation between the TEs indicates the emergence of mixed geogenic and anthropogenic sources.

Table 3. Correlation matrix between elements.

	Cd	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**Zn**
Cd	1	-0.550	0.033	-0.073	0.226	0.436	-0.380	-0.271
Co		1	0.209	0.097	0.009	-0.710*	0.451	-0.140
Cr			1	-0.268	0.462	0.030	0.073	-0.322
Cu				1	0.040	0.137	0.286	-0.118
Fe					1	0.008	-0.535	0.300
Mn						1	0.003	0.043
Pb							1	-0.610
Zn								1

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

3. 3. Factor Analysis

Table 4. Component Matrix.

	Components			
	1	**2**	**3**	**4**
Co	-0.819	0.431	0.140	0.138
Pb	-0.786	-0.513	0.138	
Cd	0.675	-0.374	0.358	
Mn	0.582	-0.601		0.165

Fe	0.447	0.579	0.419	0.497
Cr		0.242	0.895	
Zn	0.407	0.581	-0.604	
Cu	-0.197	-0.339	-0.210	0.872
Eigen value	**2.489**	**1.797**	**1.556**	**1.068**
% Variance	**31.113**	**22.467**	**19.452**	**13.350**
Cumulative %	**31.113**	**53.579**	**73.031**	**86.381**

The factor analysis of the element is shown in Table 4; this was plotted in 3-dimensional rotated space to display their relationship (Figure 1). Four components totalling 86.4% of the variance. The first component makes up 31.1% and moderate loadings with Cd and Mn, and low loadings with Fe and Zn. The second component makes up 22.5% and a moderate loading with Fe and Zn, and low loadings with Co and Cr. The third component makes up 19.5 % and has a strong loading with Cr and low loadings with Cd and Fe. The fourth component makes up 13.4 % and has strong loadings with Cu and low loadings with Co, Mn and Fe.

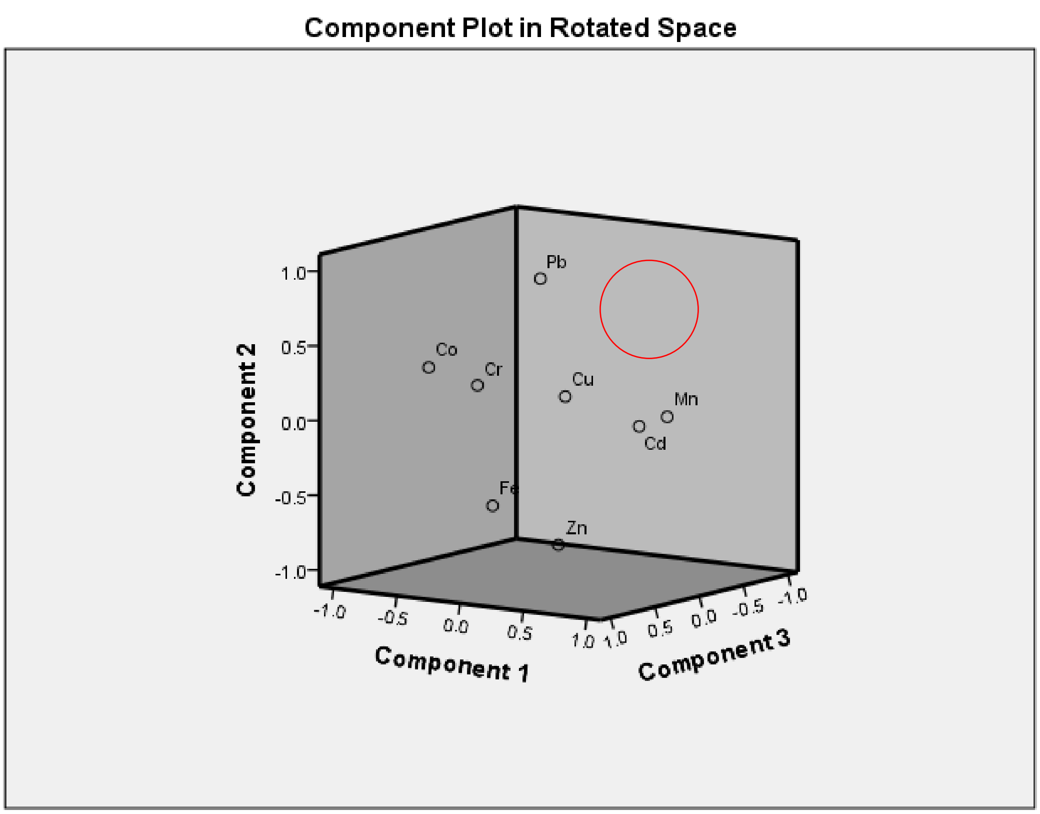

Figure 1. Factor Analysis.

4. CONCLUSION

This study evaluated the human risk assessment of toxic elements in stream sediments in Kuto-Ijeun Community, Abeokuta, Ogun State, Nigeria. Regular monitoring of persistent organic pollutants is highly required. Future studies should be targeted on the assessment of these contaminants in the aquatic biota, crops, farmers and rural dwellers of the surrounding communities in this environment. Studies should be focused on the assessment of these contaminants in different biological samples, plant uptakes, farmers, and rural dwellers in this environment to ascertain the extent of bioaccumulation of these contaminants. Remediation of toxic element in this water body is highly recommended.

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Pictorial Views of the Studied Streams

Plate 1. Ijeun- Titun Stream

Plate 2. Isabo Stream

Plate 3. Isale- Oja Kuto Stream.

Plate 4. Lafaru Stream

Plate 5. Stadium Stream