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Original Research Article

Levels of Lead (Pb) and Cadmium (Cd) in Water, Sediment, and Water Hyacinth (*Eichhornia crassipes*) in Kolo Creek

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Abstract: Heavy metal pollution in the Niger Delta's aquatic ecosystems, driven largely by crude oil exploration and industrial activities, poses significant ecological and human health risks due to the persistence and bioaccumulation of elements such as lead (Pb) and cadmium (Cd). This study aimed to assess the concentrations of Pb and Cd in water, sediment, and the aquatic macrophyte *Eichhornia crassipes* (water hyacinth) from Kolo Creek, Bayelsa State. Samples were collected from three locations along the creek over two months and analyzed using an atomic absorption spectrophotometer (AAS). The results revealed detectable levels of both metals across all matrices, with sediment samples showing the highest concentrations (Pb: 1.608–1.863 mg/kg; Cd: 0.137–0.150 mg/kg), while lower levels were found in water hyacinth (Pb: up to 0.004 mg/kg; Cd: 0.0028–0.0040 mg/kg). Statistical analysis showed strong positive correlations between metal concentrations in the different compartments. In conclusion, the study confirms that *Eichhornia crassipes* is an effective bioaccumulator of heavy metals, underscoring the significant long-term ecological risk posed by elevated sediment metal levels and highlighting the need for stricter discharge regulations and the adoption of phytoremediation strategies.

Keywords: Lead, Cadmium, Water Hyacinth (*Eichhornia crassipes*), Kolo Creek, Heavy Metals.

1. INTRODUCTION

Heavy metals are metallic elements with relatively high density that are often toxic to living organisms even at low concentrations. Their environmental significance arises from their tendency to bioaccumulate and persist in ecosystems (Ali *et al.*, 2019). The presence of heavy metals in aquatic environments can originate from both natural and anthropogenic sources. Natural inputs include volcanic activity, continental weathering, and forest fires, while anthropogenic sources include industrial effluents, stormwater runoff, leaching of metals from waste dumps, and rural metal inputs (Tchounwou *et al.*, 2012).

In the Niger Delta, heavy metal pollution is strongly linked to crude oil exploration and industrial activities. Drilling activities and the disposal of drilling muds are known sources of heavy metal contamination, while dredging for navigational access to oil wells leads to the dumping of pyrite-rich spoil on creek banks. These materials undergo weathering, releasing acidic and metal-laden effluents into the aquatic environment (Olobaniyi & Owoyemi, 2018). Additional contributions come from steel manufacturing activities and the indiscriminate dumping of municipal solid waste, including scrap metals, into water bodies.

Previous studies, such as Egborge (2002), have described heavy metals as elements essential in trace amounts for plant growth but toxic in higher concentrations. Lead (Pb) and cadmium (Cd), which are blacklisted under the European Economic Community directive on discharge of dangerous substances into aquatic environments, have been implicated in widespread ecological damage and fish mortality following accidental chemical discharges (UNEP, 1986; Wright & Welbourn, 2002).

Aquatic macrophytes are of particular interest because of their ability to accumulate heavy metals, thereby serving both as indicators of contamination and as potential agents in bioremediation (Rezania *et al.*, 2016). Water, sediments, and aquatic macrophytes form an interconnected system within aquatic ecosystems,

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each playing distinct roles in the distribution and fate of heavy metals. Water is the universal solvent and serves as the medium through which pollutants are transported and made available to living organisms (Diersing, 2009). Sediments act as both sinks and potential sources of heavy metals due to processes of deposition, binding, and resuspension (Biselli *et al*., 2005), while aquatic plants such as *Eichhornia crassipes* take up metals directly from water and sediment through their roots and tissues (Ebel *et al*., 2007; Fang *et al*., 2007).

Kolo Creek, located in Bayelsa State, Nigeria, is an oil- and gas-producing area exposed to exploration activities, gas flaring, and industrial effluents (Powell *et al*., 1987; Abowei, 2000). Communities such as Imiringi and Otuasega rely on this creek for domestic and economic activities, making it imperative to monitor its environmental quality. Lead is widely recognized as an ecotoxic metal that affects microorganisms, plants, and fish populations (Taub, 2004; Lands & Yu, 2003), while cadmium is highly toxic and has been linked to skeletal deformities, impaired kidney function, and reduced survival in aquatic organisms (Bradi, 2005; Wright & Welbourn, 2002). Both metals are non-biodegradable and persist in aquatic systems, posing long-term ecological and human health risks.

Against this backdrop, the present study was carried out to assess the levels of lead and cadmium in water, sediment, and water hyacinth from Kolo Creek. By quantifying these metals in different environmental compartments, the study provides insights into the degree of contamination, the potential for bioaccumulation, and the ecological risks posed by heavy metals in an important Niger Delta creek ecosystem (IUCN, 2012).

2. MATERIALS AND METHODS

2.1. Sample Site

The study was carried out in three locations along Kolo Creek, situated in Bayelsa State, Niger Delta, Nigeria. The creek lies between longitude 5°00'N and latitude 6°30'E and is characterised as a long and narrow meandering water body with muddy banks (Abowei, 2000). Its depth and width vary across locations, with minimum and maximum widths influenced by seasonal hydrological dynamics (Sikoki *et al*., 1998). The creek experiences tidal influences during the dry season, except at Elebele Creek, where water flows unidirectionally throughout the year. During the flood season, between May and October, water flow becomes stronger and unidirectional. In Otuasega and Imiringi creeks, tidal influence causes slight reversals in water flow during the dry season. Vegetation along the creek includes canopy-forming trees and aquatic plants such as *Bambusa astonii, Lemna spp., Cytosperma senegalense, Latriogia erecta, Cyclosorus spp.,* and *Hypnos spp. (Sikoki et al.,* 1998).

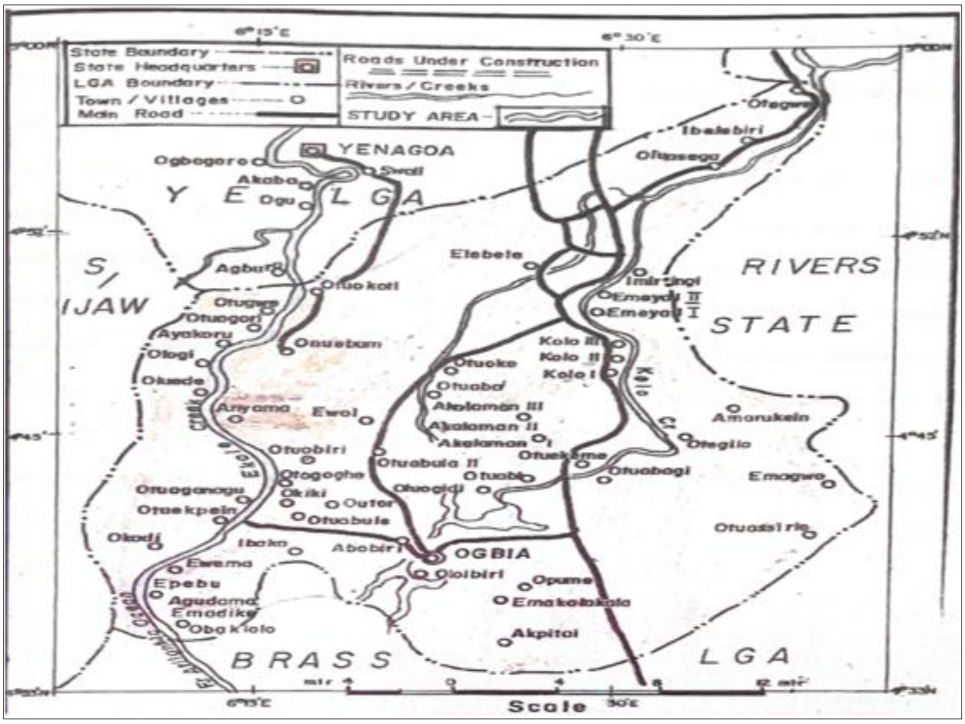

Figure 1: Map showing the study area

2.2. Environmental Sampling

Water, sediment, and *Eichhornia crassipes* samples were collected twice within two months between August and September 2015. Before collection, plastic containers used for water sampling were washed with hot soapy water, rinsed, soaked in 14% nitric acid for four hours to prevent metal adsorption, and rinsed again with deionized water before air-drying. Water samples were obtained in triplicate at a depth of 30 cm using two-liter screw-capped plastic bottles. Sediments were collected with an Eckman grab, with the top 30 cm of each sample retained in clean polythene bags. Fresh *Eichhornia crassipes* plants were handpicked and preserved in jute bags. All samples were properly labeled and kept in coolers containing ice blocks for transport.

2.3. Laboratory Analysis

In the laboratory, sediments were air-dried at room temperature, homogenised, and preserved for analysis. Water hyacinth samples were oven-dried, ground into powder with an electronic blender, and stored in plastic containers for one week before analysis.

2.3.1. Water Analysis

For water analysis, samples were aspirated directly into the flame of a Varian Tectron B Atomic Absorption Spectrophotometer (AAS). Effluent water collected from discharge points was digested before analysis.

2.3.2 Sediment Analysis

Sediments were air-dried at 40°C, ground, and sieved through a 2 mm mesh. Approximately 2.5 g of each sediment sample was digested with a nitric/perchloric acid mixture (2:1 v/v) and heated at 150°C until a clear solution was obtained. The digests were diluted to 50 mL with distilled water, filtered, and stored in labeled bottles under refrigeration until analysis using a Perkin Elmer Analyst 40 AAS.

2.3.3 Water Hyacinth (*Eichhornia Crassipes*) Analysis

Phytochemical analysis of *Eichhornia crassipes* was conducted using the paper chromatographic method described by Harborne (1973). Chromatograms were examined under ultraviolet light for the identification of compounds based on RF values, coloration, and comparison with amino acid standards (APHA, 1976). The RF value was calculated as the ratio of the distance moved by the sample to the distance moved by the solvent front.

2.3.4 Other Parameters

Other parameters analysed included nitrates, chlorides, sulfates, ammonium, zinc, copper, and phosphates. Standard methods were employed: boric acid titration for ammonium, alkaline titration for chloride, combustion methods for sulfate, and carbonate fusion for phosphate determination (Stewart *et al*., 1984; APHA, 1976).

2.4. Statistical Analyses

Statistical analyses were performed using analysis of variance (ANOVA) to test differences in heavy metal concentrations across sampling sites. The chi-square test was used to compare observed water metal concentrations against WHO (2008) standards. Pearson's product-moment correlation was used to assess relationships between metal concentrations in water, sediments, and aquatic macrophytes. Statistical significance was set at $p < 0.05$. The bioconcentration factor (BCF), which provides an index of the ability of plants to accumulate metals relative to their environmental concentrations, was calculated as described by Zayed *et al*., (1998):

$$BCF = \frac{\text{Concentration of metal in plant tissue}}{\text{Concentration of metal in water}}$$

3. RESULTS AND DISCUSSION

The physicochemical characteristics of water samples from Kolo Creek showed pH values ranging from 6.08 to 6.18, salinity between 0.02 and 0.03, conductivity values from 85.27 to 91.90 µS/cm, and turbidity levels between 25.17 and 27.60 NTU. Total dissolved solids ranged from 46.23 to 49.10 mg/L, while total suspended solids were between 5.20 and 5.91 mg/L. Other parameters included calcium (14.30–23.67 mg/L), magnesium (0.52–0.57 mg/L), potassium (0.33–0.53 mg/L), sodium (7.77–10.33 mg/L), iron (29.00–41.33 mg/L), and manganese (0.00–0.10 mg/L). Dissolved oxygen ranged from 5.98 to 6.25 mg/L, chemical oxygen demand from 23.68 to 30.97 mg/L, and biological oxygen demand from 15.01 to 15.77 mg/L. Significant variation ($p < 0.05$) was observed in carbonate, calcium, sodium, potassium, and COD values across the sites. Sediment samples revealed pH values between 6.74 and 6.82, conductivity between 185.82 and 242.62 µS/cm, total nitrogen from 5.36 to 6.01 mg/L, total organic carbon from 6.00 to 6.42 mg/L, and total hydrocarbon concentration from 6.66 to 7.00 mg/L. Heavy metal analysis showed that lead concentrations ranged from 1.608 to 1.863 mg/kg, while cadmium values ranged from 0.137 to 0.150 mg/kg.

In *Eichhornia crassipes*, lead levels varied between non-detectable and 0.004 mg/kg across stations, while cadmium concentrations ranged from 0.0028 to 0.0040 mg/kg. Results demonstrated that the macrophyte accumulated metals in its tissues, confirming its potential role as a biomonitor.

Pearson's correlation analysis indicated strong positive associations between metal concentrations in water, sediments, and macrophytes, with coefficients of 0.881 for Pb in sediments versus plants, 0.883 for Cd in sediments versus plants, and 1.000 for Pb and Cd in water versus sediments. These results highlight the interconnectedness of different environmental compartments in the distribution of heavy metals. The presence of lead and cadmium in all matrices underscores the vulnerability of Kolo Creek to contamination from anthropogenic sources, particularly oil exploration and industrial effluents. Although water concentrations appeared within WHO limits, the accumulation of metals in sediments and aquatic plants suggests a long-term ecological risk. The observed bioaccumulation in *Eichhornia crassipes* further indicates potential for biomagnification in higher trophic levels, raising concerns for fish populations and human communities that depend on the creek.

Table 1: Showing the levels of lead and cadmium, and other physiochemical parameters of water samples from Kolo Creek

Sample code	PH	SAL	COND	TURB	TDS	TSS	NO2	Cl	So4	HCO3	TA	TH	Pb	Cd	Ca	Mg	Na	K	Fe	Mn	Do	CoD	Bod
Station 1	6.18	0.02	4.90	28.50	21.50	5.65	0.126	24.00	0.54	0.30	10.0	40.0	0.001	0.002	13.96	2.50	8.54	1.80	0.15	0.02	6.50	20.70	12.80
Station 2	6.20	0.01	43.00	30.00	22.45	7.54	0.138	25.70	0.68	0.40	9.0	38.0	0.000	-0.001	14.52	2.65	7.72	2.58	0.14	0.01	6.30	18.80	12.18
Station 3	6.21	0.02	42.80	23.00	21.40	4.70	0.120	15.70	0.65	0.60	8.0	36.0	0.001	-0.001	8.86	1.85	6.58	1.60	0.18	0.02	6.80	30.20	16.70

Table 2: Showing the levels of lead and cadmium, and other physiochemical parameters of water samples from Imiringi

Sample code	PH	SAL	COND	TURB	TDS	TSS	NO2	Cl	So4	HCO3	TA	TH	Pb	Cd	Ca	Mg	Na	K	Fe	Mn	Do	CoD	Bod
Station 1	6.05	0.06	184.90	26.70	92.80	5.48	0.124	23.00	0.50	0.30	9.0	36.0	0.003	0.0012	11.56	2.20	7.46	1.74	0.12	0.02	6.45	24.60	16.50
Station 2	6.10	0.04	170.40	24.00	85.00	4.80	0.120	24.40	0.48	0.40	8.50	30.0	0.001	0.000	11.48	1.86	6.85	2.40	0.13	0.01	5.76	26.50	17.50
Station 3	6.15	0.05	166.30	25.70	83.20	5.80	0.121	13.70	0.65	0.50	8.30	28.0	0.002	0.001	7.50	1.65	4.72	0.86	0.16	0.01	6.00	32.30	15.85

Table 3: Showing the levels of lead and cadmium, and other physicochemical parameters of water samples from Otuasegha

Sample code	PH	SAL	COND	TURB	TDS	TSS	NO2	Cl	So4	HCO3	TA	TH	Pb	Cd	Ca	Mg	Na	K	Fe	Mn	Do	CoD	Bod
Station 1	6.02	0.02	66.0	27.60	33.00	5.60	0.127	24.00	0.53	0.40	12.0	48.0	0.002	0.0010	15.60	2.70	8.95	2.00	0.14	0.01	5.80	25.75	15.72
Station 2	6.20	0.01	62.30	28.50	31.20	5.40	0.118	18.48	0.54	0.30	6.80	28.0	0.001	0.001	9.64	2.86	5.40	1.80	0.14	0.02	6.20	28.60	12.80
Station 3	6.18	0.01	65.60	26.80	33.00	5.10	0.116	13.50	0.56	0.50	7.00	25.5	0.001	0.001	7.30	1.48	4.65	0.72	0.15	0.01	5.85	30.40	14.76

Table 4: Showing the levels of lead and cadmium, and other physico-chemical parameters of sediment samples from Kolo

Sample code	PH	COND	NO3	PO4	TKN	TOC	So4	CL	THC	Cu	Pb	Cd	Mg	Na	K	Fe	Mn
Station 1	7.30	193	6.75	4.86	5.30	5.88	7.85	6.50	7.66	0.398	1.863	0.143	7.52	9.50	4.76	3.78	0.45
Station 2	6.86	187.80	5.86	4.26	7.85	6.80	5.30	5.88	7.70	0.428	1.720	0.148	7.80	9.72	5.20	3.85	0.50
Station 3	6.80	185.82	5.48	3.88	7.28	6.42	4.98	5.70	7.20	0.432	1.688	0.150	8.10	1020	5.64	3.80	0.52

Table 5: Showing the levels of lead and cadmium, and other physico-chemical parameters of sediment samples from Imiringi

Sample code	PH	COND	NO3	PO4	TKN	TOC	So4	CL	THC	Pb	Cd	Ca	Mg	Na	K	Fe	Mn
Station 1	6.56	250	7.00	5.75	7.78	6.70	7.64	5.84	5.86	1.728	0.137	11.72	6.86	7.58	3.85	2.86	0.38
Station 2	6.65	242.62	6.72	5.40	5.28	6.00	6.96	6.20	6.25	1.680	0.142	12.80	7.20	7.64	4.00	3.00	0.40
Station 3	6.70	240.50	6.60	5.00	4.86	5.80	6.35	5.98	5.80	1.626	0.148	13.90	7.68	7.94	4.40	3.20	0.44

Table 6: Showing the levels of lead and cadmium, and other physico-chemical parameters of sediment samples from Otuasegha

Sample code	PH	COND	NO3	PO4	TKN	TOC	So4	CL	THC	Pb	Cd	Ca	Mg	Na	K	Fe	Mn
Station 1	6.60	260	6.70	6.25	4.96	6.68	7.48	6.60	7.48	1.775	0.138	18.84	5.57	8.80	4.20	3.54	0.40
Station 2	6.70	254.54	6.28	5.82	4.20	5.90	6.811	6.72	7.60	1.645	0.144	18.76	5.64	9.36	4.80	3.50	0.48
Station 3	6.75	248.76	6.00	5.44	3.94	5.78	6.36	6.20	6.98	1.608	0.148	19.30	6.20	9.80	5.20	3.46	0.50

Table 7: Showing the Levels of Lead (Pb) and Cadmium (Cd) in Water Hyacinth (*Eichhonia Crassipes*) From Kolo

Sample code	Pb	Cd
Station 1	0.002	0.0028
Station 2	0.004	0.0032
Station 3	0.003	0.0030

Table 8: Showing the Levels of Lead (Pb) and Cadmium (Cd) in Water Hyacinth (*Eichhonia Crassipes*) From Imiringi

Sample code	Pb	Cd
Station 1	0.001	0.0030
Station 2	0.002	0.0033
Station 3	0.002	0.0032

Table 9: Showing the Levels of Lead (Pb) and Cadmium (Cd) in Water Hyacinth (*Eichhonia crassipes*) From Otuasega

Sample code	Pb	Cd
Station 1	-0.002	0.0040
Station 2	-0.002	0.0038
Station 3	-0.001	0.0036

Table 10: Correlation (sediment)

	Otuasegha	Imiringi	Kolo
Otuasegha Pearson correlation sig (2-tailed) n	1 15	.777** .001 15	1.000** .000 15
Imiringi Pearson correlation sig (2-tailed) n	.777** .001 15	1 15	.777** .001 15
Kolo Pearson correlation sig (2-tailed) n	1.000** .000 15	.777** .001 15	1 15

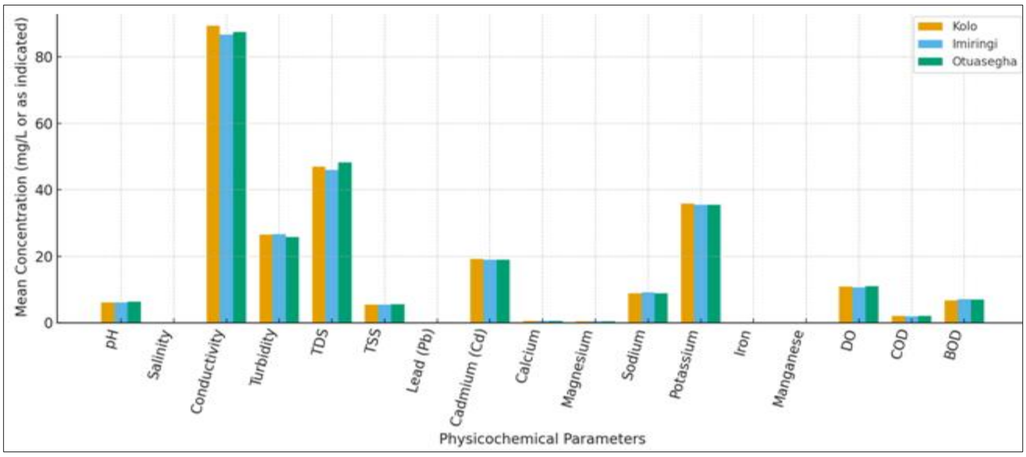

Figure 2: Graph showing the mean concentration of different physicochemical parameters in water samples collected from Kolo, Imiringi, and Otuasegha

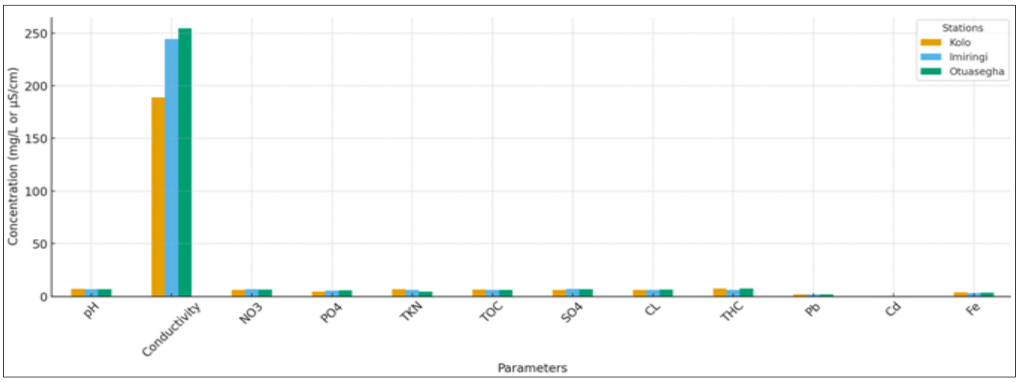

Figure 3: Mean concentration of physicochemical parameters in sediment samples (Kolo, Imiringi, and Otuasegha)

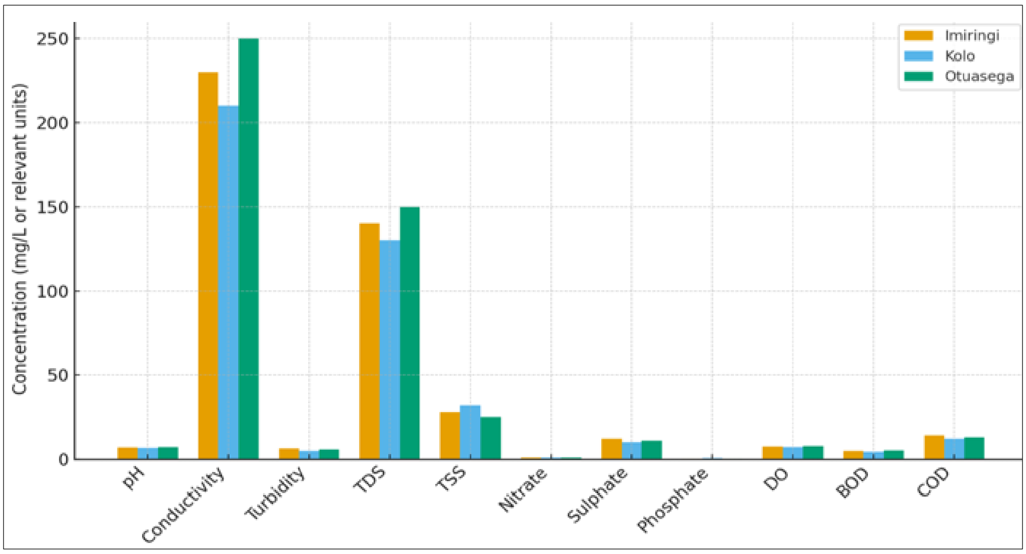

Figure 4: Comparison of physicochemical parameters of water samples

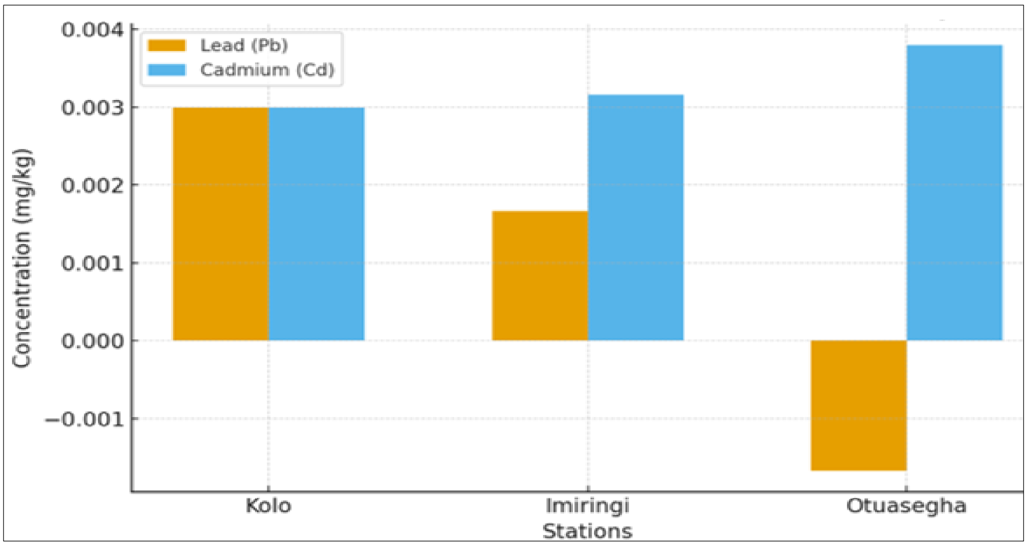

Figure 5: Mean concentration of Lead (Pb) and Cadmium (Cd) in water Hyacinth samples

4. CONCLUSION

The increased heavy metal concentrations in macrophytes, together with their corresponding high Bio-Concentration Factor (BCF) values, suggest that water hyacinth is an effective bioaccumulator of heavy metals. Although the concentrations of lead and cadmium observed in this study exceeded the recommended limits set by various regulatory agencies, their elevated levels in both sediment and water present significant risks to the aquatic ecosystem. Sediment-dwelling macrobenthos, which are fundamental components of aquatic systems, are particularly sensitive to pollution; hence, their ecological functions and the vital services they provide to humans and the environment are likely to be impaired. To address this environmental challenge, stricter legislation is needed to regulate and reduce the discharge of heavy metals into aquatic systems. In addition, promoting the use of aquatic plants such as water hyacinth, which possess the natural ability to bioaccumulate heavy metals, offers a cost-effective, environmentally friendly, and efficient alternative to conventional methods of heavy metal removal.

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Author Contributions:

Rowland Ebiere Kayla: Experiment execution, reagents/materials, and manuscript composition

Emmanuel N. Ogamba: Experimental conception, design, and supervision

Fiderikumo Livingstone Gbeinbo: Manuscript critical review

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