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# Heavy Metal Accumulation: Implication For Plant – Based Approach In Environmental Remediation

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## ABSTRACT

Soil and water contamination with heavy metals is a threat to the health of the environment all over the world. Variety of remediation techniques have been considered, most of which are not cost effective and adequate. “In this study, the concentrations of five different heavy metals ( Pb, Cu, Cr, Cd, and Zn) were determined in five naturally growing plant species, Spike edges (*Kyllinga erecta*), Purple swamp grass (*Sacciolepis Africana*), Flora of Zimbabwe (*Ludwigia abyssinica*), Caesar’s weed (*Urena lobata*) and Leaf flower (*Phyllanthus sp*) growing along Orile Canal in Lagos State. Plants, sediments and water were collected and digested prior heavy metals determination using Atomic Absorption Spectrophotometer. The order of heavy metal concentration in the water sample from the location were Cu> Cr> Pb> Ni> Cd”. The trend in the sediment samples concentrations ranged from 0 (not detected) in Cd to 49.24 mg/kg of Copper in the Orile canal. *Sacciolepis Africana* accumulate as much as 228.15mg/kg(Cu) *Phyllanthus sp* concentration of heavy metal 139.25mg/L (Cr) and other plant species from the location. The observed order of phytoremediation potential of the studied plants was *Sacciolepis Africana* > *Phyllanthus sp* > *Kyllinga erecta*>*Ludwigia abyssinica* > *Urena lobata* in totality.

**Keywords:** Concentration, hyperaccumulators, trace metals, remediation, sediment, weed

## INTRODUCTION

Water and land are essential natural resources that are necessary for agriculture and human civilization to survive. Unfortunately, because of anthropogenic activities, they have been exposed to intense “exploitation” and have been severely degraded. Human activities are largely responsible for release of pollutants. These pollutants are introduced into the environment through direct sources such discharge of effluents, Industrial solid waste, vehicle emissions, mining and smelting activities, and indirect sources such as dissolved natural or synthetic salts, along with the application of pesticides, insecticides, and excessive fertilizers in agriculture, all contribute to environmental contamination (McGrath et al., 2020). “Each of these pollution sources poses serious risks to plant and animal life, and ultimately to human health. Heavy metals are defined as metallic elements characterized by relatively high densities, atomic weights, or atomic numbers. Common examples include mercury (Hg), lead (Pb), arsenic (As), zinc (Zn), copper (Cu), nickel (Ni), chromium (Cr), and cadmium (Cd) are typical heavy metals and metalloids” examples.

Heavy metals originate from both natural and anthropogenic sources. “These include produced water from oil and gas operations (Pichtel, 2016), agricultural application of phosphate-based fertilizers (Rafique & Tariq, 2016), sewage sludge (Farahat & Linderholm, 2015), activities related to metal mining and smelting (Chen et al., 2016), pesticide usage (Iqbal et al., 2016), electroplating processes, and the combustion of fossil fuels (Muradoglu et al., 2017). In this study, metals such as copper, cadmium, nickel, and lead were specifically analyzed due to their environmental prevalence and risk. The

presence of these heavy metals in soil and water is particularly concerning because of their environmental persistence and harmful effects on human health. Although heavy metals cannot be broken down biologically, they can undergo changes in oxidation state or form various complex compounds (Alabssawy et al., 2024; Gisbert et al., 2008). Consequently, heavy metal contamination remains a significant environmental and public health issue. There are ongoing efforts to develop techniques that are simple to apply, sustainable, cheap and effective to have good quality soil, water and ensure they are free from contaminants are in place. Small-scale physicochemical methods have been utilized to treat polluted soil and water. However, they are not effective when the remediation is on the large scale and has adverse consequences (Rakhshae et al., 2017)".

In recent years, increasing attention has been given to the use of plants for decontaminating polluted soils and water—a process known as phytoremediation (Bhat et al., 2022). In the last twenty years, extensive research has been carried out in the field of phytoremediation. "The ability of various plant species to absorb and accumulate heavy metals in their biomass has prompted widespread evaluation and testing of different plants (Hu et al., 2024)". Studies have also explored the underlying mechanisms of metal uptake at both the whole-plant level and the cellular scale.

### PHYTOREMEDIATION

**Phytoremediation** is a type of bioremediation that uses plants to address environmental pollution without the need to extract and relocate contaminated materials. This process relies on specific plant species capable of absorbing, degrading, or eliminating pollutants such as heavy metals, pesticides, solvents, explosives, crude oil, and related compounds. These plants help lower contaminant levels in polluted soils, water bodies, or the atmosphere (USEPA, 2012)

**Phytoremediation** is an effective method for addressing long-term contamination in soil and stagnant water environments. It has been successfully used to mitigate the impact of pollutants in soil, water, and air, particularly in the rehabilitation of areas previously used for metal mining operations. Globally, this process has proven successful in reducing the levels of various pollutants, including metals, herbicides, solvents, explosives, and petroleum-based substances (USEPA, 2012)

It has been demonstrated that a variety of plants, "including pigweed, hemp, alpine pennycress, and mustard plants", are efficient at hyperaccumulating pollutants at "toxic waste sites."

This remediation process has been applied in locations with lead, uranium, and arsenic contaminations in soils over the last 20 years. "Phytoremediation provides the advantage of on-site environmental remediation; however, it has a significant drawback in that it demands a sustained effort as it depends on a plant's capacity to develop and flourish in an environment that is not conducive to typical plant growth (Kumar et al., 2025). Plants have the capabilities absorb ionic substances from polluted soil at low concentration. In order to absorb heavy metals and alter their bioavailability, plants extend their root systems into the soil matrix and establish a bacterial ecosystem according to Ali et al., (2013), DalCorso et al., (2019 and, Jacob et al., (2020)). This helps maintain soil fertility and supports plant-driven restoration of polluted land. Plants that naturally grow in metal-rich soils have developed the capacity to accumulate high levels of heavy metals in their tissues without exhibiting toxic effects (Bakers et al., 2020)".

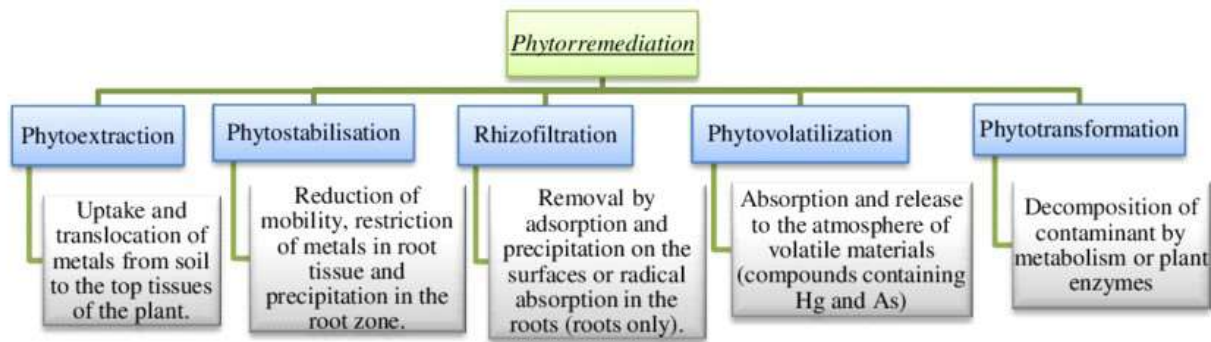
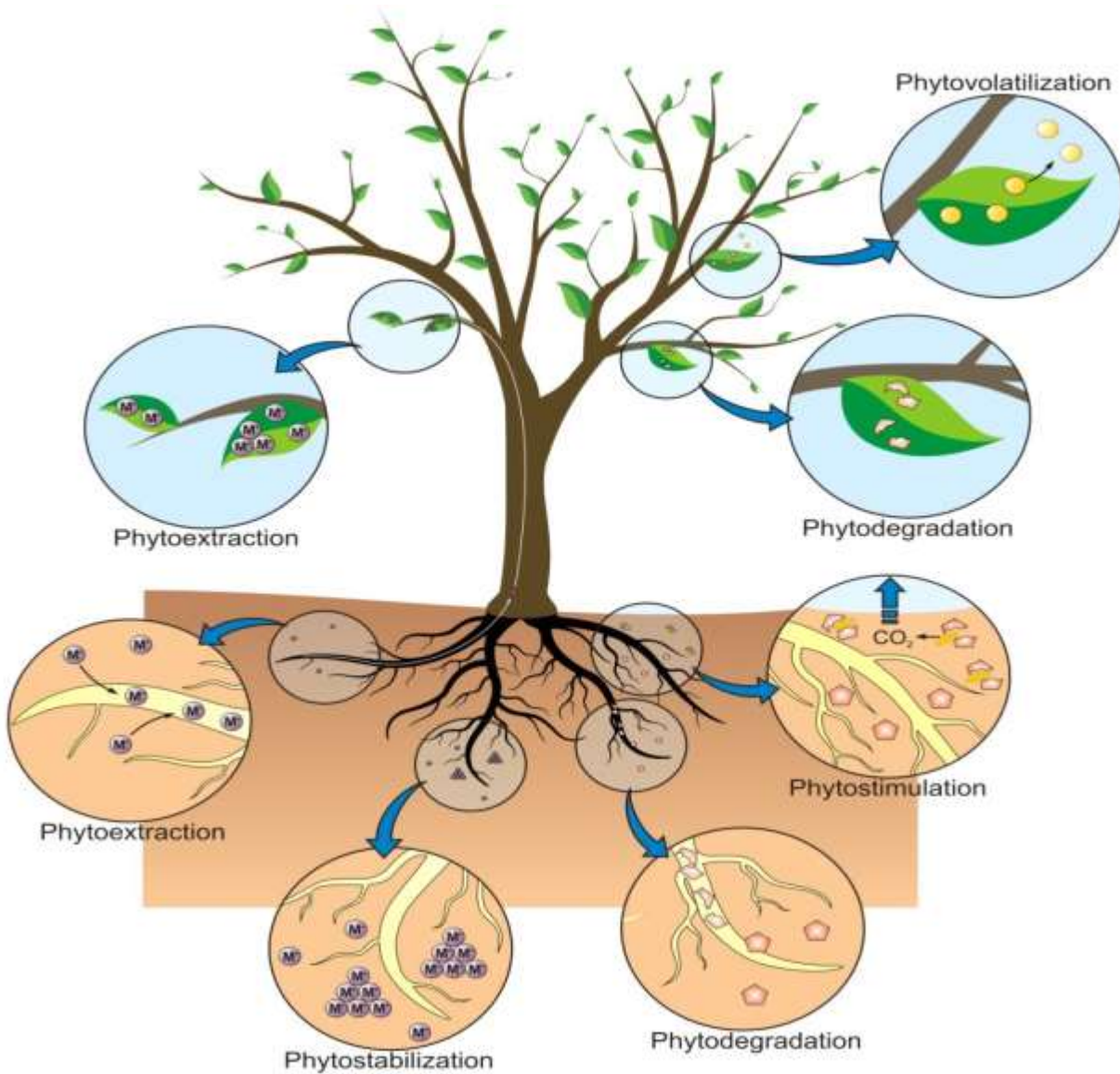


Figure 1: Types and characteristics of phytoremediation [Jing et al, 2007; Mkumbo, et al., 2012]

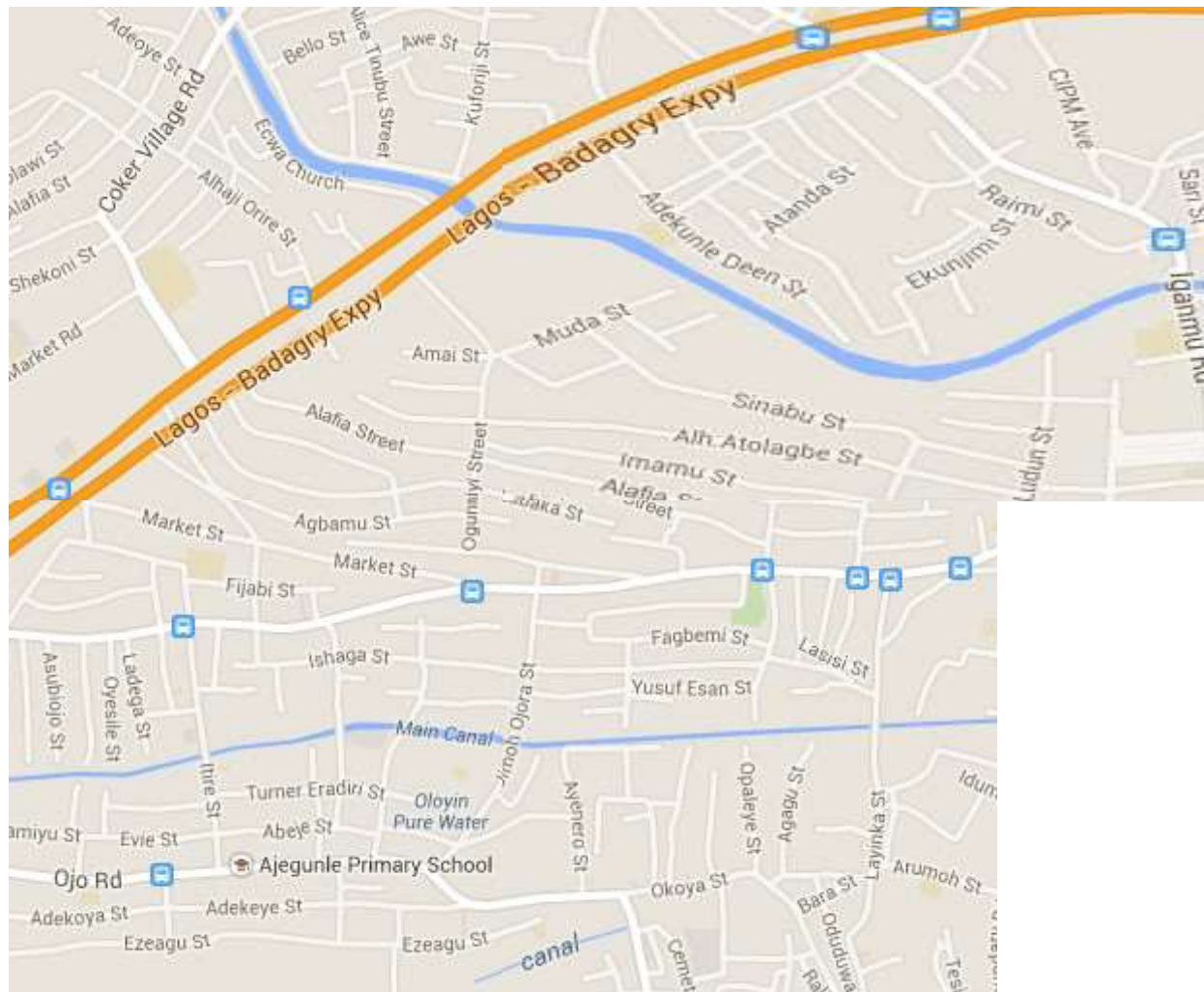


Approaches to Phytoremediation (Favas et al., 2014)

## MATERIALS AND METHODS

### Study area:

Orile canal is found at Orile via Alafia street to Jimoh Ijora street, Ajeromi-Ifelodun , Lagos State, Nigeria.



### Materials.

In this study, water, soil sediment, and plants were the sample materials examined. The sampling was done during dry season. At the sampling site, water sample was collected at a depth of 30cm into a 50 mL screw-capped polythene bottles in the center of the body of water. The bottles were cleaned with distilled water and treated with 10% nitric acid before the sampling (Laxen and Harrison, 1981). “To stop the metals from being broken down by microbes, A 5 mL volume of concentrated nitric acid was added to the water samples”. Plant samples were collected by hand, labelled, packed in nylon bags and kept for identification. Identification of the plants samples was done in the Botany Department of the University of Lagos, Akoka, Lagos State.

**Table 1: Scientific names of Plant Samples**

Labels of Samples	Botanical Names
1. Spike edges	<i>Kyllinga erecta</i>
2. Purple swamp grass	<i>Sacciolepis Africana</i>
3. Flora of Zimbabwe	<i>Ludwigia abyssinica</i>
4. Caesar’s weed	<i>Urena lobata</i>
5. Leaf flower	<i>Phyllanthus sp.</i>

**SAMPLE PREPARATION AND TREATMENT**

**Digestion of Sediment Samples.**

A clean porcelain crucible was filled with approximately 5.0g of the dried and sieved sediment samples, which were then “heated over a hot plate to ignite” and gently burn the sample. “To eliminate the carbon content (organic matter), the residue was subsequently heated to 550°C in a muffle furnace”.

“The residual material was dissolved in 10 mL of aqua regia, composed of three parts concentrated hydrochloric acid and one part concentrated nitric acid, and subsequently treated with distilled water. After filtering the resultant solution into a 100 ml standard volumetric flask, distilled water was added to the mark it”.

**Determination of Metals.**

“The digested solution was aspirated into the air-acetylene flame of the Atomic Absorption Spectrophotometer (Perkin Elmer Analyst 200) for analysis.. At a specific wavelength, each metal was identified using a particular hollow cathode lamp”.

**Determination of Metals in Water Samples**

“5ml of concentrated nitric acid were introduced to a beaker containing 100 ml of thoroughly mixed water. On a heated plate, the beaker was allowed to evaporate until it was almost completely dry. After cooling, a volume of 5 mL of concentrated nitric acid was added to the beaker. After then, heating went on until a light-colored solution was seen. One milliliter of concentrated nitric acid was added to the residue in the beaker, and the mixture was gently heated. The inner walls of the beaker were rinsed with distilled water until the total volume reached 50 mL Atomic Absorption Spectrophotometer Perkin Elmer Analyst 200 running on an air-acetylene flame was used to determine the levels of lead, cadmium, chromium, copper, and nickel in the digested samples. The particular hollow cathode lamp at a certain wavelength was used to identify each metal”.

**RESULTS AND DISCUSSION**

The analytical results are summarized in Tables 2 to 8 and Figures 1 to 7.

**Table 2: Concentration of Heavy Metals (mg/L) in Water Samples Collected from Orile Canal compared to international permissible limit.**

Parameter	Cu	Cd	Cr	Ni	Pb
<b>Orile water</b>	<b>0.08</b>	<b>ND</b>	<b>0.06</b>	<b>0.01</b>	<b>0.03</b>
<b>WHO (2022)</b>	<b>0.2</b>	<b>0.01</b>	<b>0.1</b>	<b>0.2</b>	<b>5.0</b>
<b>USEPA (2004)</b>	<b>1.3</b>	<b>0.005</b>	<b>0.1</b>	<b>0.1</b>	<b>0.015</b>

ND = Not detected

The mean concentration of Cu, Cd, Cr, and Pb in the water sample in the location were 0.08, 0.06, 0.01, 0.03 mg/L respectively. The order of heavy metal “concentration” in the water samples were “Cu> Cr> Pb> Ni> Cd”.

**Table 3: Heavy metal concentration (mg/kg) in Sediments of Orile canal**

Parameter(mg/kg)	Cu	Cd	Cr	Ni	Pb
<b>Orile</b>	<b>49.24</b>	<b>ND</b>	<b>0.79</b>	<b>0.24</b>	<b>10.09</b>
<b>WHO(2022)</b>	<b>25</b>	<b>0.5</b>	<b>50</b>	<b>03</b>	<b>35</b>

ND= Not detected

The heavy metal concentrations ranged from ND (Cd) to 49.24 mg/kg of Copper in the location. The results of the analysis are presented in tables below.

**Table 4: Heavy metal concentration of leaves of plant species collected from Orile canal**

Specie name	Cu (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
<i>Kyllinga erecta</i>	9.75	ND	3.95	ND	6.30
<i>Sacciolepis Africana</i>	35.93	0.70	89.85	0.48	5.73
<i>Ludwigia abyssinica</i>	65.30	ND	146.53	0.53	3.78
<i>Urena lobata</i>	43.73	ND	ND	0.48	8.10
<i>Phyllanthus sp.</i>	121.70	ND	139.25	0.35	0.40

Order of heavy metal accumulation in *Kyllinga erecta* was Cu>Pb>Cr>Cd>Ni. Cu was the most accumulated while Cd and Ni were the least accumulated. The highest and the least metal concentration in *Sacciolepis Africana* were Cr and Ni with the order of heavy metal being Cr>Cu>Pb>Cd>Ni. Cadmium was not detected in *Ludwigia abyssinica*. “The highest heavy metal accumulated was Cr while Cd the least. The observed concentrations of heavy metals were ranked in the following descending order: Chromium (Cr) > Copper (Cu) > Lead (Pb) > Nickel (Ni) > Cadmium (Cd). In *Urena lobata*, Cu concentration was the highest and Ni, the least. Cadmium (Cd) and Chromium (Cr) were the least abundant and were found to be below the detection limits in the analyzed sample. The concentration of heavy metals in the sample decreased in the following order: Copper (Cu) > Lead (Pb) > Nickel (Ni) > Cadmium (Cd) > Chromium (Cr). The order of heavy metal accumulation in *Phyllanthus sp.* were Cr>Cu>Ni>Pb>Cd. Cd was not detected”.

**Table 5: Concentrations of heavy metals in the shoot tissues of plants collected from the Orile Canal.**

Specie name	Cu (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
<i>Kyllinga erecta</i>	10.20	ND	ND	0.73	2.60
<i>Sacciolepis Africana</i>	89.43	ND	136.00	0.25	4.80
<i>Ludwigia abyssinica</i>	53.75	ND	122.55	0.40	3.73
<i>Urena lobata</i>	52.63	ND	ND	0.43	10.80
<i>Phyllanthus sp.</i>	45.33	ND	140.60	0.35	0.98
WHO 1996	10	0.02	1.3	10	0.3

The order of heavy metal accumulation in *Kyllinga erecta* short stem was Cr>Pb>Ni while Cd and C was not detected. In *Sacciolepis Africana*, Cr was the highest metal accumulated and Ni was the least. The heavy metal concentrations were as follows: Cr>Cu>Pb>Ni>Cd. In *Ludwigia abyssinica*, the heavy metal accumulation order was “Cr>Cu>Pb>Ni>Cd”.

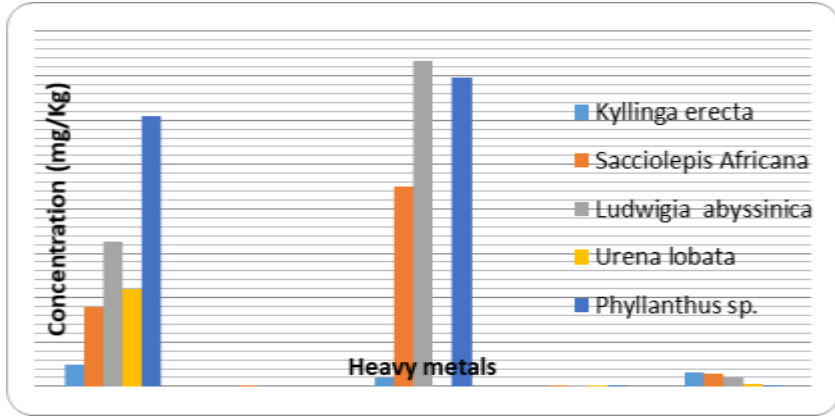
“The order of heavy metal concentration was Chromium (Cr) > Copper (Cu) > Lead (Pb) > Nickel (Ni) > Cadmium (Cd). The order of heavy metal accumulation in *Ludwigia abyssinica* was Chromium (Cr) > Copper (Cu) > Lead (Pb) > Nickel (Ni) > Cadmium (Cd). The concentration in Cd was not detected in the sample”. The highest and least accumulated metals in *Urena lobata* were Cu and Ni. Cd and Cr were not detected. *Phyllanthus sp.* contained 140.60mg/kg Cr and Cd was not detected in the sample. The order of heavy metal was Cr>Cu>Pb>Ni>Cd.

**Table 6: Heavy metal concentration in the roots of the plant species collected from Orile canal.**

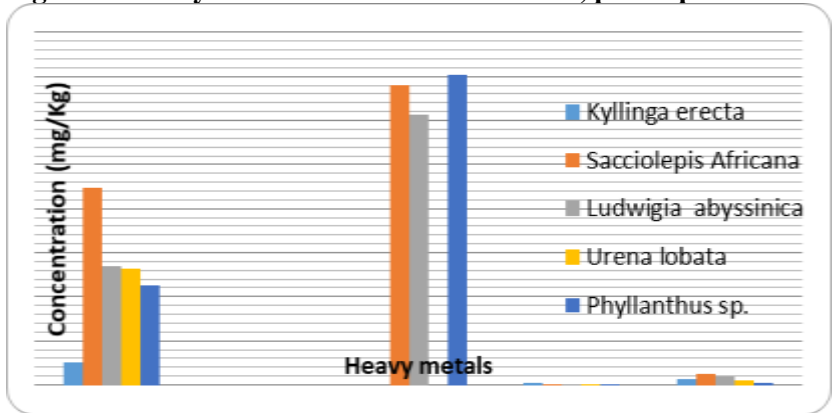
Specie name	Cu (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
<i>Kyllinga erecta</i>	91.85	ND	25.15	0.30	14.83
<i>Sacciolepis Africana</i>	228.15	ND	16.73	0.28	2.73
<i>Ludwigia abyssinica</i>	63.40	ND	48.10	0.80	3.18
<i>Urena lobata</i>	70.98	ND	ND	0.55	1.40
<i>Phyllanthus sp.</i>	ND	ND	ND	ND	ND
WHO 1991	10	0.02	1.3	10	0.3

Heavy metal accumulation in the roots of *Kyllinga erecta* was highest for Copper (Cu), followed by “Chromium (Cr), Lead (Pb), Nickel (Ni), and lowest for Cadmium (Cd). Copper was the most accumulated metal in *Sacciolepis Africana* root while Ni was the least. Among the heavy metals analyzed, Copper (Cu) exhibited the highest concentration, followed by Chromium (Cr), Lead (Pb), Nickel (Ni), and Cadmium (Cd) in decreasing order. The highest and the least accumulated metals in *Ludwigia abyssinica* root were Cu and Cd with the order of heavy metal concentration being

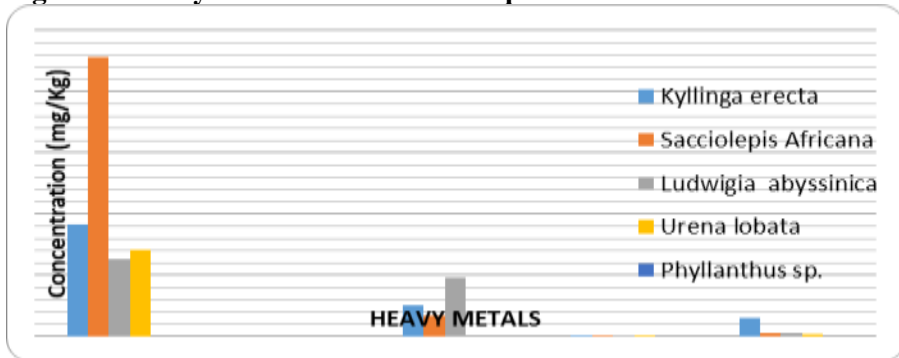
Cu>Cr>Pb>Ni>Cd”. "In the roots of *Urena lobata*, Copper (Cu) recorded the highest concentration, while Nickel (Ni) showed the lowest among the detected heavy metals. Cadmium (Cd) and Chromium (Cr) were below detectable limits. The overall order of heavy metal concentrations was: Cu > Pb > Ni, with Cd and Cr not detected.



**Figure 3: Heavy metal concentration of leaves, plant species collected from Orile canal**



**Figure 4: Heavy metal concentration in plant shoot collected from Orile canal**



**Figure 5: The concentration of heavy metals in the root tissues of the plant species sampled from Orile.**

**DISCUSSION**

The findings revealed that “the water samples obtained from the site contained heavy metals in the following order of concentration: Cu > Cr > Pb > Ni > Cd. The concentration trend of copper in the sediment samples in the Orile Canal ranged from 0 (Cd) to 49.24 mg/kg. *Phyllanthus sp.* had heavy metal concentrations ranging from ND to 140.60 mg/kg for chromium, 0 to 121.70 mg/kg for copper, 0 to 0.035 mg/kg for nickel, 0.35 mg/kg to 0 to 0.98 mg/kg for lead, and 0 to “0.40 mg/kg”. *Phyllanthus sp.* absorbed more heavy metals than *Sacciolepis africana* and other plant samples from the area, according to the results”. The observed uptake of heavy metals suggests that the plant species possesses significant hyperaccumulation capacity, highlighting its potential application in phytoremediation of contaminated environments. Cadmium is considered highly hazardous, as it exhibits toxicity even at minimal exposure levels and does not play any beneficial role in biological systems.

It should be mentioned that large concentrations of critical metals can potentially be hazardous. As a result, it is necessary to continuously monitor these metals and figure out how to remove them from the environment before the point of threshold is reached. It should be acknowledged that exceptionally harsh conditions will not sustain plant growth. Plant can be used as a tool to clean up the environment especially when used in conjunction with other methods to remediate polluted environment. The results obtained showed *Kyllinga erecta* as a potential hyperaccumulator. The results are in conformity with Lum and Chikoye, (2018) in which *Kyllinga erecta* extracted Sn, Cd, Mn, Sr and Mo from soil. Odediran *et al.*, 2021 reported that *Sacciolepis Africana* reduced Nickel in Ni –contaminated aqueous system by 99.82%, 97.75% and 99.68% for concentration of 100mg/L, 200mg/L and 300mg/L respectively. The phytoremediation potential of *Ludwigia abyssinica* obtained in the study concur with findings by Johnson *et al.*, (2019) who documented the maximum remediation efficiency of lead, zinc ,chromium and manganese greater than 70 percent in their study. Ogunkunle *et al.*, 2016 also reported the phytoextraction of Cd by *Ludwigia abyssinica*. The phytoremediation capacity of *Urena lobata* obtained in this report correlates with the results of Abidemi *et al.*, 2014 in which 1460 mg/L and 1550 mg/L of Pb was extracted by *Urena lobata* in the root and shoot respectively.

## CONCLUSION

This study shows the phytoremediation potentials of five plant species collected from Orile Canal in Lagos State Nigeria to uptake heavy metals. The results indicate that all five plant species are effective in adsorbing heavy metals from polluted water. It can be concluded that *Ludwingia abyssinica*, *phyllanthus sp*, *Sacciolepis Africana*, *Urena lobata* and *Kyllinga Amaranthus* are all good hyperaccumulators with *Ludwingia abyssinica*, *phyllanthus sp*, *Sacciolepis africana* showing higher tendency to absorb heavy metals. The findings highlight the usefulness of plants in remediating polluted soils, as some species can efficiently take up pesticides, petroleum contaminants, and heavy metals. Restoring soil quality may be aided by this and threats to the environment and human health can be reduced. Cleaning up soil and returning it to its original state can be accomplished economically and environmentally via phytoremediation. Future research can however done on commercial application of these weeds to clean–up polluted sites and methods of optimizing the process can be explored.

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