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# Phytoremediation Potential of Heavy Metals Using Vetiver and Elephant Grass Obtained from Maiganga Gombe Nigeria

Umar A. M.[1]; Saidu H.[2]; Bala U.[3]; Salees B. M.[4]

[1]Department of Science Laboratory Technology, Federal Polytechnic Kaltungo, Gombe, Nigeria
[1]Department of Biological Sciences, Gombe state University, Gombe, Nigeria
[2]Department of Biological Science, Gombe State University Gombe, Gombe, Nigeria
[3]Department of Science Laboratory Technology, Federal Polytechnic Kaltungo, Gombe, Nigeria
[4]Department of Science Laboratory Technology, Federal Polytechnic Kaltungo, Gombe, Nigeria

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**Abstract**

Heavy metal contamination of soils poses a significant environmental challenge due to its persistence, toxicity, and potential for bioaccumulation in food chains. This study evaluated the comparative phytoremediation potential of Vetiver grass (*Chrysopogon zizanioides*) and Elephant grass (*Pennisetum purpureum*) in cadmium (Cd)- and nickel (Ni)-contaminated soil under controlled pot conditions. A completely randomized experimental design was employed using five graded concentrations of heavy metals (12.5–200 mg/kg) alongside a control, with each treatment replicated three times. Soil physicochemical properties were determined prior to experimentation, while metal concentrations in soil, roots, and shoots were analyzed using atomic absorption spectrophotometry following acid digestion. Phytoremediation efficiency was assessed using bioconcentration factor (BCF) and translocation factor (TF).

Results indicated that Vetiver grass predominantly accumulated Cd and Ni in its roots, exhibiting BCF values greater than 1.0 for Cd and consistently low TF values (<1.0), indicating strong phytostabilization potential. In contrast, Elephant grass demonstrated higher translocation of both metals to aerial tissues, with TF values frequently exceeding 1.0, particularly for Cd, indicating strong phytoextraction capability. Cd accumulation was generally higher than Ni accumulation across both species and increased proportionally with applied concentrations. Soil physicochemical characteristics, particularly low organic carbon and moderate cation exchange capacity, were found to influence metal availability and uptake dynamics.

Overall, Vetiver grass functioned primarily as a phytostabilizer, while Elephant grass exhibited greater potential as a phytoextractor. The findings suggest that both species can be strategically applied in phytoremediation programs depending on site-specific remediation objectives, with Vetiver suited for metal stabilization and Elephant grass for contaminant removal through biomass harvesting.

***Keywords:*** *Phytoremediation, Bioconcentration Factor, Translocation Factor and Heavy Metals.*

## I. INTRODUCTION

Heavy metal contamination of soils has intensified globally due to expanding industrial activities, intensive agriculture, mining, and inadequate waste management practices. Among the most concerning contaminants, cadmium (Cd) and nickel (Ni) are highly mobile, non-biodegradable, and capable of bioaccumulating in food chains, thereby posing significant ecological and public health risks (Yan et al., 2020). Their persistence in soil systems is strongly influenced by physicochemical properties such as pH, organic matter, and cation exchange capacity, which collectively regulate metal mobility and bioavailability.

Conventional remediation approaches, including soil excavation and chemical immobilization, are often constrained by high cost, technical complexity, and potential degradation of soil quality (Nedjimi, 2021). Consequently, phytoremediation has emerged as a sustainable alternative that leverages plant–microbe interactions to stabilize, extract, or transform contaminants in situ. This technology is increasingly recognized as an environmentally compatible strategy for large-scale remediation of metal-polluted soils (Yan et al., 2020; Kongkham et al., 2026).

The success of phytoremediation is strongly dependent on plant functional traits, particularly root morphology, biomass productivity, and metal translocation efficiency. Fast-growing grasses are widely regarded as effective candidates due to their adaptability and extensive root systems that enhance metal uptake and immobilization (Nugroho et al., 2021). *Chrysopogon zizanioides* (Vetiver grass) is particularly noted for its deep, fibrous root architecture and strong ability to stabilize heavy metals within the rhizosphere, thereby limiting their transfer to aerial tissues (Gravand et al., 2020; Kongkham et al., 2026). In contrast, *Pennisetum purpureum* (Elephant grass) exhibits high biomass yield and efficient nutrient uptake, characteristics that favor phytoextraction through aboveground accumulation and harvestable metal removal (Nugroho et al., 2021).

Despite increasing application of both species in contaminated environments, comparative evidence under controlled conditions remains limited, particularly regarding their differential bioconcentration and translocation behavior for Cd and Ni in tropical soils. Such information is critical for matching plant species to specific remediation goals, whether stabilization or extraction, and for improving the efficiency of phytomanagement strategies.

Therefore, this study comparatively evaluates the phytoremediation potential of Vetiver grass (*Chrysopogon zizanioides*) and Elephant grass (*Pennisetum purpureum*) in cadmium- and nickel-contaminated soil. The study quantifies metal accumulation in soil–plant compartments and assesses remediation efficiency using bioconcentration and translocation factors. The outcomes aim to support evidence-based selection of high-performance plant species for sustainable remediation of heavy metal–contaminated soils in tropical agroecosystems.

## II. MATERIALS AND METHOD

- *Growth Media Soil Collection*

The soil used for phytoremediation was randomly collected from botanical garden Gombe state university from 0-30cm depth within each grid point using soil auger and meter rule. Composite sample was created by thoroughly mixing subsamples collected from slightly different locations within the grid cell. The soil sample was taken to Department of Biochemistry Laboratory for physicochemical and heavy metals analysis.

- *Physico-Chemical Properties Analysis of Growth Media*

Then, for physical and chemical experiments, soil samples were air-dried and a number of clods were kept intact to measure their specific gravity. Some of the samples were passed through a 2 mm sieve after crushing. The other part of the samples was passed through a 4.75 mm sieve to determine the stability of the aggregates (MWD) before being crushed. Electrical conductivity and soil acidity were measured by preparing a soil suspension in a ratio of 5:1 soil to water, (Fomenky et al., 2018). Soil texture was determined by hydrometer method using soil texture triangle (Oluwatosin et al., 2023). Available phosphorus was determined by Olaniran method, Olaniran et al. (2013). The total porosity (PT) was obtained from BD and PD using the equation and relationship developed by Abdallah et al., (2024). The bulk density (BD) was obtained by the gravimetric soil core method. The oxidizable organic matter was measured using the Walkley–Black wet oxidation method, where organic matter content of the fine soil particle was oxidized by chromic acid making use of the heat of sulfuric acid. Soil pH was determined in distilled water using the pH meter with water ratio of 1:2. The potassium was extracted with HCl solution and their levels determined by flame photometry (Vocciante et al. 2022). water holding capacity (WHC) was determined following the method described by Ikeda et al. (2018). Saturation moisture content was measured by weight method and field capacity moisture with a pressure plate device. Total nitrogen was measured by Oluwatosin et al., (2023).

- *Preparation for Heavy Metals Analysis of Growth Media Soil*

According to Ayangbenro and Babalola, (2017), soil preparation before analysis involves two major steps: soil pre-treatment and soil digestion.

- *Soil Pre-Treatment*

The soil sample was properly grounded using Agate mortar to enhance the oxidation of soil samples and it was passed through a 0.25 mm sieve mesh to obtain a fine particle (Ndlovu et al., 2023).

- *Soil Digestion and Heavy Metals Analysis*

In this experiment the nitric acid-perchloric acid digestion was utilized (Ande et al., 2021). 0.5g of the finely grounded soil sample was accurately weighed using a digital weighing balance and placed in a 50ml beaker. Aliquots 20ml of a mixture of nitric acid and perchloric acid in 1:1 molar ratio was poured into the soil in the beaker and the content was placed on a hot plate and heated gently at low temperature until it becomes pale yellow. The digested sample was allowed to cool before it was filtered into a 50ml standard volumetric flask which was made up to mark with distilled water and the sample was placed in storage containers and taken for analysis using atomic absorption spectrometer. Ten (10) major toxic heavy metals (cadmium (Cd), chromium (Cr), iron (Fe), arsenic (As) lead (Pb), nickel (Ni), zinc (Zn), Manganes (Mn), Cobalt (Co) and Cupper (Cu)) in the samples were determined with BUCK SCIENTIFIC 210/211VGP Atomic

Absorption Spectrophotometer (AAS) under standard method as described by Adetunji et al. (2022)

- *Plating Soil Preparation and Treatment with Heavy Metals*

The plating soil was air-dried for 7 days, grounded in to fine and sieved prior to introduce heavy metals. The experiment consists of 5 treatments of heavy metals (concentration) for each plant, each of the treatment was divided into 3 replicates. Thirty (30) pots containing 5kg of soil (fifteen pots for vetiver grass and fifteen for elephant grass) and Six (6) pots with a capacity of 5 kg soil as control of the two plants making the total of 36 pots for the experiment.

- *Planting and Harvest*

C. zizanioides (Vetiver grass) and Pennisetum purpureum (Elephant grass) young seedling (10 – 15cm) were obtained from Maiganga area kumo Akko, Gombe state Nigeria were there was no human activities. The seedlings were transplanted in to the prepared pots and acclimatization was observed for five days. The pots were placed on a tray (saucer) in order to recycle the irrigation water leaked from each pot that might contain Heavy metals (Gorovtsov et al., 2022).

Then, based on the water requirement, seedlings were irrigated with one litter of water twice a week, and temperature conditions of the greenhouse was at a constant temperature of 23–27°C during the entire growth period. The pots were continually cleared of weeds and during the growth period that lasted about 2 months (Hamidpour et al., 2020).

The experiment was terminated eight (8) weeks after planting. During harvest, the plants were carefully uprooted and washed with distilled water to remove any residual soil or dust. They were then Oven-dried at 70°C for 48 hrs. They were weighed for dry weight, and then separated into roots and shoots (Annu et al., 2018).

- *Heavy Metal Analysis of Plant Root and Shoot*

The dried plant samples (roots and shoots) were ground using mortar and pestle and sieved to <2 mm to become powdered prior to analysis according to the method of Gebeyehu & Bayissa (2020).

One gram (1g) of each powdered plant samples (root and shoot of the vetiver and elephant grass) was weighed into a beaker. Aliquots of 30 ml hydrochloric acid and 10 ml nitric acid were added and covered so as to allow for any reaction to subside. The mixture was placed on a hot plate and heated at 100ºC for about forty minutes until the digest becomes pale yellow. After digestion, the solution was allowed to cool and then filtered using 2mm filter paper. The filtrate was made up to the 50 ml volume and transferred to 60 ml plastic bottles (Abiya et al., 2019). The sample bottles were labelled. Two (2) toxic heavy metals (cadmium (Cd) and nickel (Ni)) in the samples were determined with BUCK SCIENTIFIC 210/211VGP Atomic Absorption Spectrophotometer (AAS) under standard method as described by Adetunji et al. (2022).

- *Heavy Metals Analysis of Plating Soil after Experiment*

According to Ayangbenro and Babalola, (2017), soil preparation before analysis involves two major steps: soil pre-treatment and soil digestion.

- *Soil Pre-Treatment*

All the experimental pots soil sample were properly grounded using Agate mortar to enhance the oxidation of soil samples and it was passed through a 0.25 mm sieve mesh to obtain a fine particle (wong et al., 2024).

- *Soil Digestion and Heavy Metals Analysis*

In this experiment the nitric acid-perchloric acid digestion was utilized (Ande et al., 2021). 0.5g of the finely grounded soil sample was accurately weighed using a digital weighing balance and placed in a 50ml beaker. Aliquots 20ml of a mixture of nitric acid and perchloric acid in 1:1 molar ratio was poured into the soil in the beaker and the content was placed on a hot plate and heated gently at low temperature until it becomes pale yellow. The digested sample was allowed to cool before it was filtered into a 50ml standard volumetric flask which was made up to mark with distilled water and the sample was placed in storage containers and taken for analysis using atomic absorption spectrometer. Cadmium (Cd) and nickel (Ni) in the samples were determined with BUCK SCIENTIFIC 210/211VGP Atomic Absorption Spectrophotometer (AAS) under standard method as described by Adetunji et al. (2022).

- *Bio-Concentration and Translocation Factors*

The calculation of the bio-concentration factor (BCF) and the translocation factor (TF) were performed to assess the potential ability of the plant for heavy metal accumulation. The following formulas were adopted (Dian et al., 2017):

$$BCF = \frac{Concentration\ in\ Organ}{Concentration\ in\ sediment}$$

$$TF = \frac{BCF\ of\ stem\ or\ leaf}{BCF\ of\ root}$$

Data on the bio-concentration and translocation factors were tabulated using Windows Excel and presented in table format.

## III. RESULT

- *Physicochemical Properties of the Growth Media Soil*

The physicochemical properties of the growth soil are presented in Table 1. The soil was characterized by a texture consisting of 35% sand, 40% silt, and 25% clay, which classifies the medium as a loam. Physical analysis showed a water-holding capacity of 28% and a saturation level of 6 3.00pm.

Chemical analysis indicated that the soil is slightly alkaline, with a pH (1:2 $H_2O$) of 7.65±0.05. The salinity was measured at 0.545±0.01 %, corresponding to an electrical conductivity (EC, 1:2 extract) of 429.50±2.50

µS/cm and a saturation paste extract (ECe) of 860.00±5.00 µS/cm.

Nutrient profiles revealed relatively low organic content, with organic carbon at 0.54±0.00 % and total nitrogen at 0.18±0.00 %. The soil's cation exchange capacity (CEC) was 8.63±0.01 Cmol/kg, while the exchangeable acidity was recorded at 2.84±0.01 Cmol/kg.

Table 1 Physicochemical Properties of the Growth Media Soil.

| **Parameter (Unit)** | **Mean** |
|---|---|
| Sand (%) | 35±0.01 |
| Silt (%) | 40±0.01 |
| Clay (%) | 25±0.00 |
| Water-Holding Capacity % | 28±0.01 |
| pH (1:2 $H_2O$) | 7.65±0.05 |
| EC (1:2 Extract) (µS/cm) | 429.50±2.50 |
| ECe (Sat. Paste) (µS/cm) | 860.00±5.00 |
| Salinity (%) | 0.545±0.01 |
| Organic Carbon (%) | 0.54±0.00 |
| Total Nitrogen (%) | 0.18±0.00 |
| Exchangeable Acidity (cmol/kg) | 2.84±0.01 |
| CEC (cmol/kg) | 8.63±0.01 |
| Saturation Level (%) | 63.00±0.00 |

EC=Electrical Conductivity, CEC= Cation Exchange Capacity, Mean ± Standard Error of Mean. Values with the Same Super Script in the Same Colum Indicate No Significant Difference.

- *Cadmium Concentration in Vetiver and Elephant Grass*

The cadmium (Cd) concentrations measured in soil, roots, and shoots for Vetiver Grass (*C. zizanioides*) and Elephant Grass (*P. purpureum*) across various applied concentration levels are presented in Table 2. The cadmium concentrations (Mg/kg) for Vetiver Grass across the control and five applied concentration levels increased progressively from 3.51mg/kg at the first level to 53.35 mg/kg at the fifth level. Similarly, in the Elephant Grass treatment, soil cadmium rose from 1.85 mg/kg to 37.52 mg/kg across the same range. Vetiver Grass roots accumulated cadmium starting at 5.36 mg/kg and reached a peak of 127.10 mg/kg at the highest treatment level. Elephant Grass roots showed an accumulation range from 2.75 mg/kg to 65.79 mg/kg. The concentration of cadmium in Vetiver Grass shoots remained relatively low, ranging from 3.17 mg/kg to 11.41 mg/kg. In contrast, Elephant Grass shoots displayed significantly higher translocation, with values increasing from 6.18 mg/kg to 83.15 mg/kg. The distribution of nickel across the growth media and plant tissues followed similar upward trends as applied concentrations increased. Soil nickel levels for the Vetiver Grass group increased from 5.31 mg/kg at the first level to 114.45 mg/kg at the fifth level. For the Elephant Grass group, soil nickel concentrations moved from 2.66 mg/kg to 83.74 mg/kg. Vetiver Grass roots showed nickel accumulation starting at 2.44 mg/kg and reaching 52.42 mg/kg at the fifth concentration level. Elephant Grass roots exhibited lower accumulation, ranging from 3.58 mg/kg to 21.61 mg/kg. Shoot concentrations in Vetiver Grass ranged from 1.25 mg/kg to 16.42 mg/kg. Elephant Grass demonstrated much higher nickel translocation into aerial tissues, with shoot concentrations increasing from 5.05 mg/kg to 75.05 mg/kg.

Table 2 Cadmium Concentration in Elephant and Vetiver Grass

| **Initial Concentration** | | **Vetiver Grass** | **(Cd)** | | **Elephant Grass** | **(Cd)** |
|---|---|---|---|---|---|---|
| | **Soil (Mg/kg)** | **Root (Mg/kg)** | **Shoot (Mg/kg)** | **Soil (Mg/kg)** | **Root (Mg/kg)** | **Shoot (Mg/kg)** |
| 0 | 0.07±0.00[d] | 0.28±0.00[b] | 0.12±0.00[c] | 0.01±0.00[e] | 0.12±0.00[c] | 0.36±0.00[a] |
| 12.5mg/kg | 3.51±0.12[c] | 5.36±0.15[a] | 3.17±0.05[c] | 1.85±0.02[e] | 2.75±0.01[d] | 6.18±0.02[b] |
| 25mg/kg | 7.86±0.18[c] | 11.45±0.07[b] | 2.54±0.06[e] | 4.43±0.01[d] | 1.07±0.01[f] | 15.70±0.12[a] |
| 50mg/kg | 18.64±0.12[c] | 26.42±0.15[b] | 5.77±0.06[e] | 2.90±0.01[f] | 11.39±0.10[d] | 32.42±0.15[a] |
| 100mg/kg | 37.40±0.05[b] | 54.18±0.03[a] | 12.20±0.05[d] | 24.61±0.17[c] | 13.71±0.05[d] | 54.15±0.08[a] |
| 200mg/kg | 53.35±0.12[d] | 127.10±0.10[a] | 11.41±0.05[f] | 37.52±0.15[e] | 65.79±0.18[c] | 83.15±0.10[b] |

Mean ± Standard Error of Mean. Values with the Same Super Script in the Same Row Indicate No Significant Difference

- *Nickel Concentration in Vetiver and Elephant Grass*

The Nickel (Ni) concentrations measured in soil, roots, and shoots of Vetiver Grass (*C. zizanioides*) and Elephant Grass (*P. purpureum*) across various applied concentration levels are presented in Table 3. Nickel levels of the soil increased progressively in both treatment groups. In the Vetiver pots, soil Ni rose from 5.31 mg/kg at level 1 to 114.45 mg/kg at level 5. Elephant grass soil Ni increased from 2.66 mg/kg to 83.74 mg/kg across the same range. Vetiver roots demonstrated high Ni sequestration, with concentrations increasing from 2.44 mg/kg to 52.42 mg/kg. Ni accumulation in Elephant grass roots was lower, spanning from 3.58 mg/kg to 21.61 mg/kg. Elephant grass exhibited substantial Ni translocation to the shoots, with concentrations increasing from 5.05 mg/kg at level 1 to 75.05 mg/kg at level 5. In contrast, Vetiver grass shoots showed lower accumulation, ranging from 1.25 mg/kg to 16.42 mg/kg.

Table 3 Nickel Concentration in Elephant and Vetiver Grass

| **Initial Concentration** | | **Vetiver Grass** | **(Ni)** | | **Elephant Grass** | **(Ni)** |
|---|---|---|---|---|---|---|
| | **Soil (Mg/kg)** | **Root (Mg/kg)** | **Shoot (Mg/kg)** | **Soil (Mg/kg)** | **Root (Mg/kg)** | **Shoot (Mg/kg)** |
| 0 | 0.11±0.00$^{b}$ | 0.15±0.00$^{a}$ | 0.08±0.00$^{c}$ | 0.03±0.00$^{e}$ | 0.06±0.00$^{d}$ | 0.14±0.00$^{a}$ |
| 12.5mg/kg | 5.31±0.03$^{a}$ | 2.44±0.01$^{c}$ | 1.25±0.02$^{d}$ | 2.66±0.01$^{c}$ | 3.58±0.03$^{b}$ | 5.05±1.06$^{a}$ |
| 25mg/kg | 12.61±0.11$^{a}$ | 8.44±0.05$^{b}$ | 1.04±0.05$^{f}$ | 7.73±0.15$^{c}$ | 4.31±0.02$^{e}$ | 6.31±0.05$^{d}$ |
| 50mg/kg | 31.41±0.05$^{a}$ | 7.35±0.05$^{e}$ | 2.46±0.03$^{f}$ | 13.40±0.15$^{c}$ | 8.50±0.05$^{d}$ | 23.14 ±0.11$^{b}$ |
| 100mg/kg | 61.51±0.11$^{a}$ | 25.32±0.05$^{c}$ | 3.28±0.02$^{e}$ | 51.32±0.14$^{b}$ | 17.17±0.03$^{d}$ | 24.53±0.17$^{c}$ |
| 200mg/kg | 114.45±0.14$^{a}$ | 52.42±0.17$^{d}$ | 16.42±0.05$^{f}$ | 83.74±0.23$^{b}$ | 21.61±0.15$^{e}$ | 75.05±0.13$^{c}$ |

Mean ± Standard Error of Mean. Values with the Same Super Script in the Same Row Indicate No Significant Difference

- *Phytoremediation Performance Metrics (BCF and TF) for Vetiver and Elephant Grass*

The phytoremediation potential of *C. zizanioides* (Vetiver grass) and *P. purpureum* (Elephant grass) was quantitatively assessed using the Bioconcentration Factor (BCF) and Translocation Factor (TF) across five initial concentration levels (12.5 mg/kg to 200 mg/kg) as shown in Table 4. For Cadmium, *C. zizanioides* displayed a high capacity for root-based accumulation, with BCF values consistently exceeding 1.0 across all treatments, starting at 1.53 and peaking at 2.40 at the highest concentration. Despite this high bioconcentration, its TF values remained significantly below 1.0, decreasing from 0.59 at the first level to 0.09 at the fifth level. This combination of high BCF and low TF indicates that *C. zizanioides* effectively sequesters Cadmium within its root system. In contrast, *P. purpureum* exhibited a strong phytoextraction profile for Cadmium. Its TF values were consistently greater than 1.0, reaching a maximum of 14.70 at the 25 mg/kg level and 1.26 at the 200 mg/kg level, suggesting efficient transport of the metal from the roots to the harvestable shoots. The BCF for *P. purpureum* fluctuated across levels, with a notable peak of 3.93 at the third concentration level.

The metrics for Nickel revealed a different accumulation strategy between the two species. *C. zizanioides* generally showed restricted uptake of Nickel, with BCF and TF values remaining below 1.0 at all concentration levels. Its BCF ranged between 0.23 and 0.67, while its TF varied from 0.12 to 0.51, suggesting that Vetiver grass acts as a metal excluder for Nickel under these experimental conditions. Conversely, *P. purpureum* demonstrated a higher affinity for Nickel translocation. While its BCF was above 1.0 only at the first level (1.35), it maintained TF values greater than 1.0 for four out of the five treatments, reaching a peak TF of 3.50 at the 200 mg/kg level. The data overall indicates that *C. zizanioides* primarily functions as a phytostabilizer for Cadmium due to its high root-retention capacity, whereas *P. purpureum* demonstrates characteristics of an efficient phytoextractor for both Cadmium and Nickel through its superior translocation capabilities.

Table 4 Phytoremediation Performance Metrics (BCF and TF) for Vetiver and Elephant Grass

| **Concentrations** | **Plant** | **Heavy Metals** | **BCF** | **TF** |
|---|---|---|---|---|
| 12.5mg/kg | *C. Zizaniodes* | Cd | 1.53 | 0.59 |
| | | Ni | 0.46 | 0.51 |
| | *P. Purpureum* | Cd | 1.50 | 2.25 |
| | | Ni | 1.35 | 1.41 |
| 25mg/kg | *C. Zizaniodes* | Cd | 1.46 | 0.22 |
| | | Ni | 0.67 | 0.12 |
| | *P. Purpureum* | Cd | 0.24 | 14.70 |
| | | Ni | 0.56 | 0.22 |
| 50mg/kg | *C. Zizaniodes* | Cd | 1.42 | 0.22 |
| | | Ni | 0.23 | 0.34 |
| | *P. Purpureum* | Cd | 3.93 | 2.84 |
| | | Ni | 0.63 | 2.72 |
| 100mg/kg | *C. Zizaniodes* | Cd | 1.45 | 0.23 |
| | | Ni | 0.41 | 0.13 |
| | *P. Purpureum* | Cd | 0.60 | 3.90 |
| | | Ni | 0.34 | 1.43 |
| 200mg/kg | *C. Zizaniodes* | Cd | 2.40 | 0.09 |
| | | Ni | 0.46 | 0.31 |
| | *P. Purpureum* | Cd | 1.75 | 1.26 |
| | | Ni | 0.26 | 3.50 |

## IV. DISCUSSION

The growth media soil for vetiver and elephant grass is classified as a loam (35% sand, 40% silt, 25% clay), a texture characteristic of highly productive agricultural land that Nithya Krishnan et al. (2024) note provides an optimal environment for root penetration, aeration, and water retention. The soil exhibits a saturation level of 63%, a water-holding capacity of 28%, a non-saline electrical conductivity (ECe) of 860 µS/cm that Ahmad et al. (2025) confirm is ideal for sensitive crops, and a slightly alkaline pH of 7.65, which Mohammad et al. (2025) indicate can significantly impact nutrient solubility. Furthermore, the soil has a low organic carbon content of 0.54% and a total nitrogen content of 0.18%, which agrees with Wong et al. (2024) that soil organic carbon levels below 1.0% indicate low-fertility systems, highlighting a critical 2026 sustainable agriculture focus for organic amendments. This low organic matter likely drives the low-to-moderate cation exchange capacity (CEC) of 8.63 cmol/kg, a threshold that Ciric et al. (2024) demonstrate makes soils susceptible to nutrient leaching during heavy irrigation or rainfall.

When exposed to heavy metals, the residual soil concentrations of both Cadmium (Cd) and Nickel (Ni) increased progressively across treatment levels, reaching 53.35 mg/kg Cd and 114.45 mg/kg Ni in Vetiver pots compared to 37.52 mg/kg Cd and 83.74 mg/kg Ni in Elephant grass pots. This linear scaling conforms to findings by Abdallah et al. (2024) and Wu et al. (2025) regarding applied spikes in controlled pot experiments. The two grasses showed a clear divergence in their remediation mechanisms for both metals. Vetiver grass acted as a phytostabilizer, sequestering the majority of its Cd and Ni in its dense root system—reaching peaks of 127.10 mg/kg Cd and 52.42 mg/kg Ni—while maintaining much lower shoot concentrations of 11.41 mg/kg Cd and 16.42 mg/kg Ni. This behavior is in agreement with Wasino et al. (2025) and Atangana & Oberholster (2024), who highlight Vetiver's ability to lock heavy metals in the rhizosphere and protect its aerial tissues using an excluder survival mechanism. For Cadmium, Vetiver maintained a Bioconcentration Factor (BCF) up to 2.40 but a Translocation Factor (TF) as low as 0.09, while for Nickel, it kept both BCF (0.23–0.67) and TF (0.12–0.51) values strictly below 1.0.

In contrast, Elephant grass functioned as an efficient phytoextractor by moving metals from roots to shoots, resulting in peak shoot concentrations of 83.15 mg/kg Cd and 75.05 mg/kg Ni that significantly exceeded its root concentrations. This aligns with the high-biomass remediation model discussed by Zhang et al. (2024) and Kumar et al. (2025), as well as reports in BioResources classifying Pennisetum purpureum as an exceptional phytoremediator capable of storing large quantities of Cd without lethal phytotoxicity. Elephant grass demonstrated an exceptionally high Cadmium TF of 14.70 at the 25 mg/kg level, attained a Cd BCF of 3.93 at the 50 mg/kg level, and maintained a Nickel TF exceeding 1.0 in four of five treatments, peaking at 3.50. This active transport is supported by Kumar et al. (2025), who note that the plant maintains a high Translocation Factor for Nickel due to its robust vascular system and high transpiration rates. The high aerial accumulation of metals also aligns with 2024–2026 research into bioenergy crops where harvested contaminated biomass is used for phytomining or energy production (Zhang et al., 2024). Ultimately, while the alkaline pH generally decreases metal solubility, the low organic carbon may have increased the plants' physiological ion demands to facilitate uptake as supported by Wu et al. (2025), demonstrating a complementary utility where Vetiver provides erosion control and metal stabilization while Elephant grass achieves active soil decontamination through periodic biomass harvesting.

## V. CONCLUSSION

This study comparatively assessed the phytoremediation potential of Vetiver grass (*Chrysopogon zizanioides*) and Elephant grass (*Pennisetum purpureum*) in cadmium (Cd)- and nickel (Ni)-contaminated soil under controlled conditions. The findings demonstrated clear species-specific differences in metal uptake, distribution, and translocation behavior. Vetiver grass consistently exhibited higher metal retention in the root system, with bioconcentration factors (BCF) greater than 1 for Cd and comparatively low translocation factors (TF), indicating limited movement of metals to aerial tissues. This confirms its strong phytostabilization capacity, making it suitable for immobilizing contaminants within the rhizosphere and reducing their environmental mobility. In contrast, Elephant grass showed greater translocation of Cd and Ni to shoots, with TF values frequently exceeding 1, particularly for Cd, demonstrating its effectiveness as a phytoextractor capable of removing metals through harvestable biomass. Across both plant species, cadmium exhibited higher accumulation levels than nickel, suggesting greater bioavailability and uptake efficiency under the experimental soil conditions. The physicochemical characteristics of the soil, including slightly alkaline pH and low organic carbon content, likely influenced metal mobility and plant uptake dynamics.

Overall, the results indicate that Vetiver grass is more appropriate for phytostabilization strategies, while Elephant grass is better suited for phytoextraction-based remediation approaches. The combined or strategic use of both species may therefore offer an integrated and sustainable approach to managing heavy metal-contaminated soils, depending on site-specific remediation goals.

## RECOMMENDATIOS

- Deploy vetiver grass for Localized Containment: Utilize *Chrysopogon zizanioides* on contaminated sites where the primary environmental objective is to stop the migration of heavy metals into neighboring ecosystems, groundwater tables, or the human food supply.

- Utilize Elephant Grass for Active Site Decontamination: Implement *Pennisetum purpureum* in areas requiring true extraction and removal of pollutants from the soil matrix, ensuring that a rigorous schedule of periodic above-ground biomass harvesting is maintained.

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