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The Use of Cyperus *iria* Linn. and *Echinochloa colona* Stapf. for the Phytoextraction of Cadmium and Lead from Contaminated Soil at Abandoned Metal Scrap Dumpsite

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***Abstract**:*
This study investigated Cd and Pb uptake by Cyperus iria Linnand Echinochloa colona Stapf from contaminated soils enhanced with NPK fertilizer at rate of 40, 80 and 120g. AComplete Randomized Design was adopted. The research was conducted at the Center for Ecological Studies, University of Port Harcourt.Heavy metal contaminated soil (2kg) was arranged in 4 batches 4 batches (A, B and C) alongside with uncontaminated soil (batch D). A and B were each subdivided into 3 sub-plots and amended as follows: A: (40g NPK/2kg + Cyperus iria; 80g NPK/2kg + Cyperus iria and 120g NPK/2kg + Cyperus iria);B: (40g NPK/2kg + Echinochloa colona; 80g NPK/2kg + Echinochloa colona and 120g NPK/2kg + Echinochloa colona) while C (which had polluted soil with no amendment) and D (with unpolluted without amendment) were set up as control and double control experiments. This was monitored at 60-day interval.The addition of NPK caused pH increase and decrease in chloride (3687-283) sulphate (269-92.41) and conductivity (1193-209)phytoextracted with the test plant species. Translocation factor was greater than 1 for Cd and Pb in Cyperus iria grown in 40g NPK/2kg. Translocation factor was also greater than 1 for CdinEchinochloa colonagrownin 40g NPK/2kg and 120g NPK/2kg amended soil. The test plants are suitable for remediation of Cd and Pb contaminated soil, Cyperus iria can be classified as Cd and Pb accumulator plant while Echinochloa colonacan be classified as Cd accumulating plant based on theseobservations.

***Keywords**: Phytoextraction; Cyperus iria; Echinochloa colona; heavy metals; phytoextraction; soil chemical properties.*

1. Introduction

Soil which is a natural resource that sustains man through agriculture is often degraded through anthropogenic activities. Point and non-point sources are responsible for this degradation by increasing heavy metals concentration in the environment (Goyer, 2001).The negative effects of heavy metals contamination have attracted concern globally because of their persistence in the environment, their tendency to accumulate along the food chain and their toxicity. Increased quantities of heavy metalsenhanced their uptake by plants. Heavy metals influenced soil physicochemical properties such as pH value, organic matter and essential plants nutrients in soil (Fytianos *et al*., 2001). The changes in physicochemical properties of soil significantly affect heavy metals bioavailability (Ge *et al*., 2000). Conventional engineering methods used in heavy metals remediation are expensive and such practise renders the soil sterile for agricultural activities. Phytoremediation which is an aspect of bioremediation have been long practiced as a feasible techniquein heavy metal remediation. The techniques have been implemented globally in pot and field experiments by researchers. Phytoremediation is more suitable than the conventional methods but is being limited on the foundation of slow growth, shallow root system, time consumption and metal immobility. Conversely, the use of synthetic chelator such as ETDA have been adopted in addressing this pitfalls in phytoremediation techniques(Tandy *et al*., 2006).The essence of adding synthetic chelator is to improve the mobility of heavy metals into solution phase and subsequently increased metal mobility from roots to shoots of plants. The use of synthetic

chelators has been limited, because its application to soil negatively influenced the growth performance of plants (Sun *et al.*, 2009). Soil amendments are important input which improves soil quality for enhancing the growth rate and performance of plants in heavy metals polluted sites. Amendments such as pig manure, sewage sludge, orange and plantain peelsare effective in reducing the toxic effect of heavy metals on plant species and it also provides a gradual release of essential plant nutrients that support growth such as nitrogen, phosphorus and potassium (Amadi *et al*., 2017). The addition of amendments into soils enhances metal sorption and mobility into solution phase (Amadi *et al*., 2017). The addition of inorganic and organic amendments such as pig manure, sewage sludge, compost, fertilizers and waste, is a common practice for immobilization and amelioration of heavy metals in soils. Some researchers report that amendment of contaminated soils with organic and inorganic amendments reduced bioavailability of heavy metals (Augustine and Marta, 2012).
The aim of this study was to evaluate the capacity of inorganic fertilizer applied at different rates in inducing phytoextraction of Pb and Cd by *Cyperus iria* and *Echinochloa colona* in polluted soil.

2. Materials and Methods

2.1. Study Location And Experimental Design

This study was carried out at the Centre for Ecological Studies, University of Port Harcourt. It is locatedon: latitude 4^o 65' N and longitude 7^o 5' E inthe Niger Delta area of Nigeria. Complete Randomized Design was adopted for the study. Weighing balance (Setra 480S, USA) was used to weigh 2kg of homogenized soil collected from an abandoned scrap site was weighed into each of planting bags of the following dimensions: height 18 cm, 14 cm diameter and 0.095 m^2. Surface area. The planting bags were arranged in 4-3 batches (A, B, and C), alongside with uncontaminated soil designated as batch D of 12 replications. Batches A and B were sub divided into 3 sub plots while batch C (control polluted soil) and D (double control unpolluted) represented as P and UP respectively were divided into 2 sub- plots.

2.2. Amendment Treatment

The amendment NPK treatment was applied as follows:

BATCHES	TREATMENT AND PLANT SPECIES
Batch A	40g NPK/2kg + *Cyperus iria*
	80g NPK/2kg + *Cyperus iria*
	120g NPK/2kg + *Cyperus iria*
Batch B	40g NPK/2kg + *Echinochloa colona*
	80g NPK/2kg + *Echinochloa colona*
	120g NPK/2kg + *Echinochloa colona*
Batch C	0g /2kg + *Cyperus iria*
	0g/2kg + *Echinochloa colona*
Batch D	0g /2kg + *Cyperus iria*
	0g/2kg + *Echinochloa colona*

Table 1: Experimental design and treatment application

After two weeks of post remediation treatment, the seedlings of *Cyperus iria* and *Echinochoa colona* raised in nursery were transplanted from nursery into batch A, B, C and D as shown in Table 1. Watering was done twice a day (6am and 6pm) and weeds control was done by hand- picking method when necessary. The experiment was monitored at 60 days interval. Soil analysis was done after contamination and at termination of the experiment at 60 days interval. The baseline analysis was done to ascertain the level of cadmium and lead in soil prior to induce phytoextraction. The second soil heavy metal analysis was done at 60 days intervals to determine the extent of phytoextraction by test plants from soil. At 60th day, six (6) replications were harvested from each bag destructively, having the shoots cut off from roots. All samples of soil and plant parts with properly labelling in accordance to their treatments were taken to the laboratory for Cd and Pb content determination. The collected soil samples were air dried and filtered through 2 mm sieve to obtain homogenous soil mass. The soil was analyzed by Atomic Absorption Spectrophotometer (Buck scientific 200A model) after digestion on a hot plate for 15 minutes with 3 mL perchloric acid and 5 mL nitric acid. The soil physicochemical properties such as conductivity, pH, sulphate and chloride were determined as follows: the pH and conductivity were determined electronically using glass electrode pH meter (HANN HI Series).Soil sulphate was determined using UV visible spectrophotometer by adding 250 ml KH_2PO_4, and shaking for 30 minutes and allowed to stand for 5 minutes (APHA 2004). Soil chloride was titrated with $AgNO_3$ solution (APHA 2004).

The plant translocation factor, accumulation factor and bioaccumulation factor were also calculated.

Translocation Factor (TF) is given as the ratio of concentration of metal in the shoot to that in the roots. It was evaluated using the formula according to Cui*et al*. 2007 as follows:

$$TF_{Cd} = \frac{c(Cd)shoot}{c(Cd)root} \text{ and } \quad TFPb = \frac{c(Pb)shoot}{c(Pb)root}$$

Bioaccumulator factor (BF) was calculated with the formula according to Baker (1981) as follows:

$$BF_{Cd} = \frac{c(Cd)plant}{c(Cd)soil} \text{ and } \quad BF_{Pb} = \frac{c(Pb)plant}{c(Pb)soil}$$

2.3. Data Analysis

The data generated were subjected to statistical analysis of variance (ANOVA) using Statistical Analysis System (SAS, 2002).Further validity of differences among treatment means was estimated usingthe Least Significance Difference (LSD) method. The Cu and Pb transport from soil to plant and from roots to shoots were evaluated using the translocation factor and accumulation factor respectively. The percentage reduction of metals was calculated by the total concentration of elements by the initial status of elements presents in soil.

3. Results

The highest pH of 8.91 and 8.23 were obtained with120g NPK/2kg amendment phytoextracted with *Cyperus iria* and 80g NPK/2kg with *Echinochloa colona* at 60 and 120 days. Soil chloride content increased in NPK amended soil of various amendment concentrations regardless of the plant species. Highest chloride content at 60^{th} day was found in 120gNPK/2kg for both plants and at 120 days in 40g NPK/2kg for both plant species. Addition of 40gNPK/2kg decreased sulphate content in *Cyperus iria* phytoextracted soil while the least decrease in sulphate was found in control soil for *Echinochloa colona* phytoextrated soil at 60 and 120 days.Both plant species grown in Pb and Cd contaminated soil with NPK amendment showed decrease in conductivity at 60 and 120 days as compared to control while the least decrease was found in double control for both plant species at 60 and 120 days. (Table 2).

Table 3. Showed the phytoaccumulation of Pb in shoot, root and total biomass of *Cyperus* in various concentrations of NPK 20:20:20 at 60 and 120 days. At 60 days of cultivationhighest concentration of Pb was found in shoot of *Cyperus iria* grown in control soil (0g amendments)and for root in 120g NPK/2kg amendment. The highest accumulation of Pb in shoot and root at 120 days was observed for *Cyperus* sp grown in soil amended with 40g NPK/2kg.

Results presented in Table 4 showed variation in the phytoaccumulation of Cd in shoot, root and total biomass of *Cyperus* in various concentrations of NPK 20:20:20 at 60 and 120 days. The applicationof inorganic amendment influenced Cd availability negatively. At 60 days, highest concentration of Cd was found in shoot of *Cyperus iria* grown in control soil (0g amendment) and for root in soil amended with 120g NPK/2kg.The highest accumulation of Cd in shoot and root at 120 days was observed for *Cyperus* sp grown in 40gNPK/2kg amended soil.

As shown in Table 5. there was variation in the phytoaccumulation of Pb in shoot, root and total biomass of *Echinochloa colona* in various concentrations of NPK 20:20:20 at 60 and 120 days.*Echinochloa* sp grown in 40gNPK/2kg showed highest increase of Pb in shoot and root at 60 days. The shoot Pb accumulation at 120 days was found in 40gNPK/2kg which was significantly higher ($p<0.05$) while the highest accumulation of Pb in root was found in control soil (polluted with 0g amendment).

The highest accumulation of Cd in shoot and root of *Echinochloa colona* at 60days was found in control soil (polluted with 0g amendment) and 80gNPK/2kg amended soil respectively. While there was an increase in Cd concentration in test plant roots and shoots with time. The highest Cd accumulation n shoot and root at 120 days was found for*Echinochloa* sp grown in 40g NPK/2kg amended soil (Table 6).

There was a significant decrease in the concentration of Pb in soil after phytoextraction with *Cyperus iria* at 60 days which further decreased at 120 days when compared to initial polluted and unpolluted soils. There was a significant reduction of Pb in amended soil.The least decrease was found at 60 daysin soil amended with 80gNPK/2kg and at 120 days in soil amended with 120gNPK/2kg phytoextracted with *Cyperus iria* (Table 7). The least reduction of Pb as shown in Table 8 was observed at 60 and 120 days amended with 120g/2kg and phytoextracted with *Echinochloa colona.*There was a significant decrease in the concentration of Cdin soil after phytoextraction at 60 days with *Cyperus iria* which further decreased at 120 days as compared to initial polluted and unpolluted soils. There was a significant reduction of Cd in amended soil. The least reduction was found at 60 days in soil amended with40gNPK/2kg and at 120 days in soil with0gNPK/2kg amendment phytoextracted with *Cyperus iria* (Table 9). The least reduction of Cd as shown in Table 10, was found in 0g NPK/2kg amended soil at 60 days and 40gNPK/2kg amended soil at 120 days phytoextracted with *Echinochloa colona.*

Table 11 showed the accumulation and translocation factor of heavy metals in parts of *Cyperus iria* at 60 and 120 days. Bioaccumulation factor (BF) was found to be less than 1 at 60 and 120 days. Mobility of Pb from root to shoot was enhanced with 40gNPK/2kgamendment showing translocation factor (TF) greater than 1 at 60 days while at 120 days TF was shown as 1.02<1.27<1.59 for 40g, 80g and 120gNPK/2kg soil amendment respectively. It was observed that BF was greater than 1in *Echinochloa* sp grown in control and double control soil at 60 days and it was less than 1 at 120days (Tale 7b), while TF was found to be less than 1 at 60 days and greater than 1 at 120 days in 120gNPK/2kg amendment. Bioaccumulation factor (BF)of Cd was greater than 1 in *Cyperus iria* grown in amended and un-amended soil (Table 13). The highest bioaccumulation factor was found at 60 and 120 days in test plants grown at 40gNPK/2kg amendment. Translocation factor greater than 1 was found at 60 days in 40gNPK/2kg and at 120days in 40gNPK/2kg and 120gNPK/2kg which showed the highest value (1.04).

Bioaccumulation factor (BF) of Cd was greater than 1 in *Echinochloa colona* grown in amended and un-amended soil. The highest bioaccumulation factor was found in *Echinochloa* sp grown in 40gNPK/2kg amended soil at 60 and 120 days. Translocation factor greater than 1 was found at 60 days 40gNPK/2kg and less than 1 at 120 days in 120gNPK/2kg amended soil (Table 14).

4. Discussion

Soil pH plays a crucial role in nutrients and heavy metals' availability in soil. This influences the efficiency of plant based remediation processes (Zulfiqar *et al*., 2012). Soil pH was increased with the addition of inorganic amendments. This observation is understandable since the pH content of NPK as tested showed an increase in pH value. The increase in soil pH content observed with the addition of NPK was similar to the observations of Motior*et al*. (2013) who reported that addition of N fertilizer increases soil pH from 5.8 to 6.5 at 56 days of cultivation. The application of remediation treatments of various concentrations decreases soil chemical properties such as levels of sulphate, chloride and conductivity. This observation is considered since increase in levels of sulphate, chloride content and conductivity were high in polluted soil (baseline). Sulphate and chloride are trace elements needed by plants in small quantities. Increase in sulphate, chloride and conductivity negatively influenced the growth rate and general performance of plants.

The addition of inorganic amendment aided the various levels of absorption of Pband Cd in the test plants. The levels of this uptake of Pb and Cd decreased with time. The highest accumulation of Pb and Cd in shoot and root at 120 days was found in *Cyperus* sp grown in 40gNPK/2kg amended soil, *Echinochloa* sp grown in 40gNPK/2kg showed highest increase of Pb content in shoot and root at 60 days. The extent of accumulation of Pb in the shoot at 120 days was found in 40gNPK/2kg which was significantly higher ($p<0.05$).The highest Cd accumulation in shoot and root at 120 days was found for *Echinochloa* sp grown in 40g NPK/2kg amended soil (Table 4).This could be attributed to the concentration of the amendment used. This is understandable since the addition of NPK in the soil increase the biomass and general performance of plants. This increase in heavy metal accumulation of plants in inorganic amendments is in line with the findings of Ho *et al.,* (2008) who reported that inorganic amendment (fertilizer) in promoting biomass yield results in bioaccumulation of heavy metals in individual plants.

A comparison of the heavy metals of the scrap soil with literature report confirmed that metals such as Pb and Cd were above the acceptable limits as presented by regulatory bodies shown in Table 15. The test plants *Echinochloa colona* grown in 120g/2kg NPK amended soil at 60 and 120 days, showed a decrease in the concentration of Pb to the permissible limits prescribed by Dutch standards while the test plants grown in 40g/2kg NPK amended soil decreased the concentration of Pb to the permissible limits in soil at 60 and 120 days according to WHO standard. The possible explanation to the variation observed in the reduction of studied heavy metals in soil could be attributed to accumulation of high heavy metal concentrations in shoots and roots of test plants. This also explains why the uptake of metals varied between the various levels of amendments used for the plants. This finding is similar to the observation of Salt*et al*. (1995) who reported that plants have different needs for elements including essential and trace metals at separate times and their uptake rates vary. Hence, bioaccumulation of heavy metals is plant species dependent. This implies that certain biochemical factors might influenced the transport mechanisms of nutrients in plants.

The BF and TF ratio were calculated in order to evaluate the accumulation of elements in plants from soil to roots in order to ascertain the phytoremediation efficacy of the test plants in the presence of amendments. Bioaccumulation factor greater than 1 showed that the studied heavy metals were retained more in the plants grown with amendment than in unamended soil. Accumulation factor less than 1 indicates non phytoaccumulation while greater than 1 shows phytoaccumulation. (by hyper accumulator). Plants with accumulation factor greater than 1 and those with accumulation factor less than 1 are classified as accumulators and excluders respectively (Amadi and Tanee, 2014). However, according to the criteria presented above, *Cyperus iria* tested in 40g NPK/2kg amended soil could be classified as hyper accumulator for Cd and Pb while *Echinochloa colona*testedin 40g NPK/2kg and 120g NPK/2kg amendments could be classified as hyper accumulator for Cd. A possible explanation may be the use of NPK fertilizer as amendment. This is understandable because NPK fertilizer increases biomass yield of plants. This increase might have influenced the uptake of heavy metals in plants due to physiological modifications. This is corroborating with findings of Ho*et al.,* (2008) who reported that inorganic amendment (fertilizer) promotes biomass yield through medium that results in bioaccumulation of heavy metals in individual plants.

5. Conclusion

The tested plant species have the potential to reduce and accumulate heavy metals in their biomass without showing morphological signs of toxicity. The accumulation of the studied heavy metals was concentrated more in shoots of plants grown in NPK amended soil. This implies that accumulation of metals varies with amendment and plant species. Therefore, *Cyperus iria* tested in 40g NPK/2kg amended soil could be classified as hyper accumulator for Cd and Pb while *Echinochloa colona*tested in soil with 40g NPK/2kg and 120g NPK/2kg amendments could be classified as hyper accumulator for Cd. Therefore,*Cyperus iria* and *Echinochloa colona*were observed to effectively ameliorate Cd and Pb polluted conditions and thus the plant species could be considered in remediating Pb and Cd contaminated sites using phytoremediation techniques.

60days	***Cyperus iria* in NPK amendments**			**Cp**	**Up**	***Echinochloa* in NPK amendments**			**Cp**	**Up**
	40g	**80g**	**120g**	**0g**	**0g**	**40g**	**80g**	**120g**	**0g**	**0g**
pH	8.21±0.24	8.31±0.04	8.91±0.01	8.3±0.01	6.13±0.1	8.04±1.04	8.23±0.4	7.89±0.14	8.3±0.03	6.3±0.33
Chloride (mg/kg)	212.7±0.05	212.73±0.03	283.5±0.04	141.87±0.16	141.8±6	232.7±0.38	229.7±2.3	295.3±0.02	141.7±0.06	141.8±0.1
Sulphate (mg/kg)	69.62±0.18	80.4±0.2	92.33±0.03	92.41±0.2	84.11±0.05	166.4±0.2	176.9±0.016	232.01±0.69	92.41±0.2	84.11±0.05
Conductivity	213±0.14	209±0.1	209.3±4	865±8.0	90.3±4.9	265.7±2.5	207±0.2	259.3±0.21	500±0.12	92±2.0
120 days	**40g**	**80g**	**120g**	**0g**	**0g**	**40g**	**80g**	**120g**	**0g**	**0g**
pH	8.44±0.4	8.95±0.03	8.33±0.4	8.2±0.1	6.43±0.24	8.27±0.01	8.14±0.02	8.25±0.2	8.04±0.14	5.67±0.03
Chloride	283.6±0.12	141.8±0.03	143±2.13	141.8±2	144.3±0.667	232.37±0.318	154.07±0.667	154.07±0.067	145.03±0.7	142.3±0.667
Sulphate	73.83±0.025	92.19±0.018	29.65±0.101	71.67±0.51	483±0.06	90.7±0.08	183.3±0.57	243.3±0.033	108.7±1.2	85.73±0.49
Conductivity	265.7±0.1	207±0.4	259.3±0.06	500±9	90.3±7	237.7±4.0	214±11	191.3±10.0	1000.7±24	91.67±14

Table 2: Soil pH influenced by various concentration of NPK fertilizer with Cyperus iria and Echinochloa colona grown in amended and non-amended soil over time

Concentrations	**60 days**			**120 days**		
	Shoot	**Root**	**Total**	**Shoot**	**Root**	**Total**
40g NPK/2kg	6.4±0.08^{a}	6.15±0.3^{b}	12.55^{b}	24.0±0.01^{a}	23±3.2^{a}	47.0^{a}
80g NPK/2kg	6.3±0.1^{b}	6.65±0.1^{b}	12.95^{b}	18.0±0.01^{b}	14±1.31^{b}	32.0^{b}
120g NPK/2kg	0.1±0.002^{c}	22.6±5.0^{a}	22.7^{a}	16.0±0.1^{bc}	9.8±0.55^{cd}	26.0^{bc}
0g NPK + Polluted soil (control)	6.23±0.01^{b}	0.4±0.005^{c}	6.63^{c}	8.2±0.4^{c}	10±3.3^{c}	18.2^{d}
0g NPK + Unpolluted soil (double control)	0.1±0.002^{c}	0.2±0.002^{c}	0.3^{d}	0.4±0.004^{d}	0.4±0.06^{e}	0.8^{e}

Table 3: Phytoaccumulation of Pb (mg/kg) in Cyperus iria

Concentrations	60 days			120 days		
	Shoot	Root	Total	Shoot	Root	Total
40g NPK/2kg	8±0.06[a]	7±0.08[b]	15.0[a]	17±0.03[a]	39.1±0.01[a]	56.1[a]
80g NPK/2kg	5.6±0.12[b]	7.3±2.0[b]	12.9[c]	12±0.2[b]	14.7±0.13[b]	26.7[b]
120g NPK/2kg	4.7±0.13[b]	8.43±3.0[a]	13.13[b]	15±0.4[ab]	14±0.03[b]	29.0[b]
0g NPK + Polluted soil (control)	8.7±0.7[a]	4.2±0.1[c]	12.9[c]	9±0.33[c]	9±0.08[c]	18.0[c]
0g NPK + Unpolluted soil (double control)	1.4±0.06[c]	2.9±0.2[d]	4.3[d]	1.63±0.1[e]	4.5±0.04[e]	6.13[d]

Table 4: Phytoaccumulation of Cd (mg/kg) in Cyperus iria

Concentrations	60 days			120 days		
	Shoot	Root	Total	Shoot	Root	Total
40g NPK/2kg	7.5±0.03[a]	26±6.0[c]	33.5[b]	20±0.25[a]	29±9.0[b]	49.0[b]
80g NPK/2kg	7.5±0.02[a]	16±3.5[d]	23.5[cb]	13±4.0[b]	18±2.0[c]	31.0[c]
120g NPK/2kg	0.1±0.01[b]	7.5±3[e]	7.6[d]	14±6[b]	10±3.0[d]	24.0[c]
0g NPK + Polluted soil (control)	7±0.09[a]	87.0±1.5[a]	94.0[a]	0.02±0.33[c]	83±2.0[a]	83.0[a]
0g NPK + Unpolluted soil (double control)	0.1±0.001[b]	46±3.0[b]	46.1[e]	0.16±0.33[c]	7±0.01[d]	7.16[d]

Table 5: Phytoaccumulation of Pb (mg/kg) in Echinochloa colona

Concentrations	60 days			120 days		
	Shoot	Root	Total	Shoot	Root	Total
40g NPK/2kg	5.6±0.05[b]	5.3±1.0[b]	10.9[ab]	20.0±1.3[a]	14.8±0.8[d]	35.0[a]
80g NPK/2kg	5.7±0.02[b]	6.23±0.1[a]	11.93[a]	13.0±1.4[b]	16±2.0[b]	29.0[b]
120g NPK/2kg	6.6±0.06[a]	5±0.12[b]	11.6[a]	14.3±1.5[b]	15±1.0[c]	29.3[b]
0g NPK + Polluted soil (control)	6.7±0.3[a]	4.5±0.04[cb]	11.2[a]	0.02±0.33[e]	6±0.9[a]	6.02[c]
0g NPK + Unpolluted soil (double control)	4.1±0.2[c]	3.2±0.06[d]	7.3[b]	0.16±0.33[c]	6±1.0[e]	6.16[c]

Table 6: Phytoaccumulation of Cd (mg/kg) in Echinochloa colona

			NPK treatment of various concentrations				
	P	**Up**	**40g**	**80g**	**120g**	**0g (P)**	**0g (UP)**
60days	167.3 ±7.0^{a}	130 ±0.1^{bc}	106.58±0.19^{c}	96.55±0.25^{d}	95.4±0.61^{d}	134±1.85b	34±0.15^{e}
120 days	167.3 ±7.0^{a}	130 ±0.1^{b}	103.7±0.3^{c}	89.1±0.1^{d}	86±0.03^{d}	131±1^{b}	21±1^{e}

Table 7: Concentration of Pb in soil phytoextracted with Cyperus iria

			NPK treatment of various concentrations				
	P	**Up**	**40g**	**80g**	**120g**	**0g (P)**	**0g (UP)**
60days	167.3 ±7.0^{a}	130 ±0.1^{b}	131.7±0.01^{b}	94.44±0.18^{c}	67.4±0.18^{d}	91±0.033^{c}	34.23±0.01^{e}
120 days	167.3 ±7.0^{a}	130 ±0.1^{b}	100±0.27^{c}	80.5±0.175^{d}	64.33±0.199^{e}	85±0.04^{d}	16.3±1.309^{f}

Table 8: Concentration of Pb in soil phytoextracted with Echinochloa colona

			NPK treatment of various concentrations				
	P	**Up**	**40g**	**80g**	**120g**	**0g (P)**	**0g (UP)**
60days	15.3 ±2.0^{a}	0.80 ±0.01^{c}	0.08±0.003^{c}	0.13±0.015^{b}	0.15±0.001^{b}	0.08±0.003^{c}	0.04±0.3^{d}
120 days	15.3 ±2.0^{a}	0.80 ±0.01^{c}	0.04±1^{dc}	0.12±1^{b}	0.12±1^{b}	0.04±0.1^{dc}	0.2±0.2^{e}

Table 9: Concentrationof Cd in soil phytoextracted with Cyperus iria

			NPK treatment of various concentrations				
	P	**Up**	**40g**	**80g**	**120g**	**0g (P)**	**0g (UP)**
60days	15.3 ±2.0^{a}	0.80 ±0.01^{b}	0.06±0.01^{c}	0.05±0.03^{c}	0.04±0.03^{d}	0.04±0.1^{d}	0.03±0.003^{e}
120 days	15.3 ±2.0^{a}	0.80 ±0.01^{b}	0.01±0.01^{d}	0.04±0.8^{c}	0.04±0.15^{c}	0.05±0.1^{c}	0.02±0.003^{d}

Table 10: Concentrationof Cb in soil phytoextracted with Echinochloa colona

Concentrations	**60days**		**120days**	
	BF	**TF**	**BF**	**TF**
40g NPK/2kg	0.11	1.04	0.49	1.02
80g NPK/2kg	0.13	0.94	0.36	1.27
120g NPK/2kg	0.24	0.01	0.29	1.59
0g NPK +(control)	0.05	0.97	0.14	0.81
0g NPK + (double control)	0.01	1 .0	0.05	0.98

Table 11: Accumulation Factor and Translocation Factor of metals in parts of Cyperus sp at 60 and 120 days

Concentrations	60days		120days	
	BF	TF	BF	TF
40g NPK/2kg	0.22	0.28	0.50	0.68
80g NPK/2kg	0.29	0.46	0.39	0.73
120g NPK/2kg	0.76	0.01	0.38	1.37
0g NPK + Polluted soil (control)	1.03	0.01	0.97	0.002
0g NPK + Unpolluted soil (double control)	1.34	0.002	0.43	0.02

Table 12: Accumulation Factor and Translocation Factor of metals in parts of Echinochloa sp at 60 and 120 days

Concentrations	60days		120days	
	BF	TF	BF	TF
40g NPK/2kg	187.5	1.14	1401.0	1.43
80g NPK/2kg	99.7	0.75	224.1	0.82
120g NPK/2kg	87.2	0.55	241.6	1.04
0g NPK + Polluted soil (control)	161.3	0.98	450.8	0.82
0g NPK + Unpolluted soil (double control)	109.5	0.51	30.65	0.36

Table 13: Accumulation Factor and Translocation Factor of metals in parts of Cyperus sp at 60 and 120 days

Concentrations	60days		120days	
	BF	TF	BF	TF
40g NPK/2kg	181.0	1.04	2969.0	0.99
80g NPK/2kg	236.2	0.89	686.75	0.71
120g NPK/2kg	300.5	1.22	676.75	0.80
0g NPK + Polluted soil (control)	280.0	0.89	258	0.8
0g NPK + Unpolluted soil (double control)	244.4	0.72	580	0.93

Table 14: Accumulation Factor and Translocation Factor of metals in parts of Echinochloa sp at 60 and 120 days

Trace metals	DPR soil	FEPA soil	WHO soil	Dutch soil	WHO plants
Cd	0.01	0.01	0.09	0.8	0.02
Pb	0.05	0.05	0.5	85	2

Table 15: The permissible limits of the studied heavy metals in plants and soil by the following regulatory bodies in mg/kg

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