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Hyper Accumulation of Heavy Metals by Selected Plants Insoil-Pant Media of Conterminated Municipal Solid Waste Dumpsites in Makurdi.

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Abstract

Heavy metal uptake by plant tissues was investigated by planting selected vegetable plants (hyper-accumulant) in potted soils from the different dumpsites in Makurdi andnurtured by necessary agronomic and irrigation practices to maturity. At maturity the plants were harvested whole, dried and blended in the laboratory for analysis for heavy metals. The metals uptake by selected hyper-accumulant, concentration left in the soil after extraction by hyper-accumulantwere determined. Amaranthus (white seed) removed up to 39.5% of Zinc mean concentration from Under bridge dumpsite. Amaranthus (Black) removed up to 48.5% of Copper and 39.9% of lead mean concentration from K/Ala street dumpsite. Pumpkin was able to remove up to 48% about 40% Arsenic and about 61% of chromium's Naka Road dumpsite. Analysis of variance (ANOVA) was used to estimate variation among group means in the samples by a factorial design. The effects of the site and plant and also their interactions on heavy metal up take by plants were analyzed by Duncan multiple rang test and LSD values were 0.01510, 0.2350, 0.5172, 0.06723, 0.01668, and 0.06105 for As, Cr, Cu, Fe, Pb and Zn respectively was for interaction effects of plants and site on the uptake of metals by plant and 0.02031, 0.3788, 0.1416, 0.3217, 3.381 and 0.4233 As, Cr, Cu, Fe, Pb and Zn respectively was for interaction effects of plants and site on the uptake of metals by soils. This implies that wastes dumped at these sites are heterogeneous and these plant have similar uptake potentials.

Keywords; Soil-Plant Media, Heavy Metals, Hyperaccumulation, Vegetable crops, MSW Dumpsites

I. INTRODUCTION

The use of compost from dumpsite to improveagricultural yield (without the knowledge of possible negativeeffects of waste compostswhen applied to improve soils)has become a common practice among farmers. Considering the edible part of the plant in most vegetable species, the risk of transference ofheavy metals from soil to humans should be a matter of concern (Jordoa*et al.*, 2006). Uptake of heavy metals by plants andsubsequent accumulation n is apotential threat to animal and human health (Sprynsky *et al.*, 2007). The absorption by plant roots is one of the main routes ofentrance of heavy metals in the food chain (Jordoa*et al.*, 2006).Absorption and accumulation of heavy metals in plant tissue depend upon many factors which includetemperature, moisture, organic matter, pH and nutrientavailability (Tu*et al.*, 2004; BurkenSchnoor,1996); Merkl*et al.*, 2005).

Heavy metal accumulation in plants depends upon plant species and the efficiency of different plants in absorbing metals is evaluated by either plant uptake or soil to plant transfer factors of the metals (Khan *et al.*, 2008).Specific plant species can absorb and hyper accumulate metal contaminants and/or excess nutrients in harvested root and shoot tissue, from the growth substrate through phytoextraction process (Cho-Ruk*et al.*, 2006). This is for metals, metalloids, radionuclides, nonmetals, and organics contaminants in soils, sediments, and sludge medium (USEPA, 2002; Pradf*et al.*, 2003)

Phytoremediation has been proposed as a cost-effective plant-based approach of remediation that takes advantage of the ability of plants to concentrate elements and compounds from the environment and to metabolize various molecules in their tissues (ReichenauerandGermida, 2008). It refers to the natural ability of certain plants called hyper accumulators to bio accumulate, degrade, or render harmless contaminants in soils, water, or air (Das,2018). While organic pollutants can biodegradedtoxic heavy metals cannot be degraded. Several field trials confirmed the feasibility of using plants for environmental clean-upof toxic heavy metals and organic pollutants which are the major targets for phytoremediation (Salt*et al.*, 1998). It can be a time-consuming process, and it may take at least several growing seasons to clean up a site. The intermediates formed from those organic and inorganic contaminants may be cytotoxic to plants (Mwegoha, 2008).Knowledge of the physiological and molecular mechanisms of phytoremediation began to emerge in recent years together with biological and engineering strategies designed to optimize and improve phytoremediation. Several field trials confirmed the feasibility of using plants for environmental cleanup. (Rand,*et al.*,1995).This Study used one of the Bioremediation technologies by planting some selected plants to remediate soils contaminated by heavy metals. This could be seen as the treatment of Makurdi dump sites soils contaminated by heavy metals by use of some selected hyper-accumulant through a process of phytoremidiation.

The use of dumpsites as farm land is a common practice in urban and sub-urban centers in Nigeria because of the fact that decayed and composted wastes enhance soil fertility (Ogunyemi*et al.,* 2003).Many urban population plant crops at dump sites contaminated by heavy metals and these heavy metals are known to cause deadly diseases to the human body as most of these plants during harvest carry some traces of these heavy metals in them which are harmful to the human body. Theyare significant environmental pollutants and their presence is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons (Jaishankar *et al.*, 2013; Nagajyoti *et al.*, 2010). High concentrations of these metals may inhibit plant growth and, thus, may limit application on some sites. A major limitation in the phytoremediation of toxic elements is the maximum level that can be accumulated by plants (Bieby*et al.*, 2011). Plants which can take of toxic metal from soils are known as "hyper accumulators", They generally exhibit, on a dry weight basis, from about 2000 ppm (0.2%) for more toxic elements (Cd, Pb) to above 2% for the less toxic ones (Zn, Ni, Cu) (USDE, 1994). The treatment is generally limited to soils at one meter root depth from the surface and groundwater within a few meters of the surface with soil amendments may be required (Mwegoha, 2008).The aim of this study was to determine heavy metals uptake by selected hyper-accumulant.

II. METHODOLOGY

Experimental procedures

The Global Positioning System (GPS) technology was used to identify and locate all the dumpsites in Makurdi. Representative sample dumpsites were selected from each of the categorized structure for Makurdi based on urban activities (institutional, commercial, hospital and industrial).Visiting the dump sites, interaction with nearby settlements directly affected as well as checking the type of wastes that were dumped on these dump sites were done.

Sampling of soils

Soil samples were collected from the waste dumpsites from a depth of 0-60cm(Nuonom*et al.*, 2000), preserved in clean polyethylene bags with tight plastic clips, labeled properly on the field and then taken to the laboratory. (Leke*et al.*, 2011).Soils from these samples with known concentrations of heavy metals werepotted in customized so as to plant hyper-accumulants. The hyper-accumulants used include (Amaranthus black seed,Amaranthus improved seed, Waterleaf and Pumpkin) One hyper-accumulant was planted in pots with atleast two strands in RCBD of for P1S1, P2S1, P3S1, P4S1, P1S2, P1S2, P2S2, P3S2, P4S2, P1S3, P2S3, P4S3, P4S4, P2S4, P4S4, P1S5, P2S5, P3S5, and P4S5. Each combination was replicated four times and each replicate had four pots totally 240 pots.

Planting of thehyper-accumulants plants do not have special planting procedure, they were planted with the normal agronomicpractices unique to each plant. The seeds of some were planted and the stems of some were used. Randomization was used in planting the four hyper-accumulants in the five different soil including control. Randomized Complete Block Design (RCBD) was used in to arrange the pots on the field.

Harvesting

After the plants had grown to full maturity, all the plants were harvested whole pot by pot according to soil treatment as shown in Plate1 indicating soils as well as the plants. The four were analyzed for heavy metals. Replicates of each treatment were pooled together to give composite sample of each treatment.

Plate 1: (a) Plants harvested and (b) Bagged soil and plant samples after harvest for Laboratory Analysis

Evaluation of Heavy metals in the harvested plants

The plants were washed in water to eliminate soil, dirt, possible parasites or their eggs, and finally with deionized water (Yusuf *et al.*, 2003). Each subsample was oven-dried at 70°C for 24 hours. Acid digestion method of Yusuf *et al*., 2003, was used for the digestion of grounded plant samples. 1 g each of this was weighed into 50 ml beaker, followed by addition of 10 ml mixture of analytical grade acids: HNO_3: H_2SO_4 $HClO_4$ in the ratio 1 : 1 : 1. The beakers containing the samples were covered with watch glasses and left overnight.

The digestion was carried out at temperature of 70°C until about 4 ml was left in the beaker. Then, a further 10 ml of the mixture of acids was added. This mixture was allowed to evaporate to a volume of about 4ml. After cooling, the solution was filtered to remove small quantities of waxy solids and made up to a final volume of 50 ml with distilled water. Heavy metal concentrations were determined using Atomic Absorption spectrophotometer (AAS) (Yusuf *et al.*, 2003).

III. RESULTS ND DISSCUSSION

Results of heavy metal uptake in the plants

Duncan multiple range test was used in analyzing the data and comparing means from Table 1 – 3 this test uses alphabets in comparing the means (a, b, c…….) if more than one mean carry the same alphabet it means there’s no significant difference between but the treatments they carry different alphabets, it means that the treatments are statistically different.

Tables 1 and 2: present the result of the effect of sites and plant species on the uptake of heavy metals from respective while Table 3 is the interaction effects of plants and site on the uptake of metals by plant

Table 1: Effects of sites on the uptake of metals by plants

Site	Cu	Fe	Zn	As	Cr	Pb
Uam road(S1)	1.2717 a	7.192 a	1.1833 a	0.0183 b	0.2100 b	0.2283 a
Under bridge(S2)	0.5000 c	5.448 d	0.5167 d	0.0183 b	0.1417 c	0.1425 c
k/Ala(S3)	0.5933 c	6.111c	0.7442 c	0.0167 b	0.1183d	0.2092ab
Naka(S4)	0.9975 b	6.753 b	1.0650 b	0.0275 a	0.2392 a	0.1917 b
Control (S5)	0.0033 d	0.053 e	0.0967 e	0.0000 c	0.0000e	0.0000 d
L. S. D(0.01)	0.1175	0.2586	0.03362	0.00755	0.01668	0.03052
F pr.	<.001	<.001	<.001	<.001	<.001	<.001

Note: Alphabets used in the table (Table1 to 3) are the formant of Duncan multiple range test (DMRT) statistical analysis used on this table to show difference and similarities in means

Table 2: Effects of plants on the uptake of metals by plants.

Plant	As	Cu	Fe	Zn	Cr	Pb
P1	0.01333 a	0.6893 a	5.135 a	0.7053 b	0.1413 a	0.1573 a
P2	0.01600 a	0.7087 a	5.106 a	0.7420 a	0.1407 a	0.1587 a
P3	0.01800 a	0.6933 a	5.132 a	0.7213 ab	0.2392 a	0.1500 a
P4	0.01733 a	0.6013 a	5.073 a	0.7160 ab	0.1467 a	0.1513 a
L. S. D (0.01)	0.00675	0.1051	0.2313	0.03007	0.01492	0.02730
F pr.	0.520	0.172	0.943	0.110	0.733	0.893

Table 3: Interaction effects of plants and site on the uptake of metals by plant

PLANTS	SITES	As	Cu	Fe	Zn	Cr	Pb
P1	uam road	0.02000 abc	1.3033 a	7.187 ab	1.1300 cd	0.2167 bc	0.2500 a
P2	uam road	0.02000 abc	1.3500 a	7.180 ab	1.2133ab	0.2067 bc	0.2367 a
P3	uam road	0.01333 abcd	1.2433ab	7.520 a	1.1533bc	0.2000c	0.2133 ab
P4	uam road	0.02000 abc	1.1900 ab	6.880 b	1.2367 a	0.2167bc	0.2133 ab
P1	Underbridge	0.00667 cd	0.4900 c	5.437 e	0.5267 h	0.1433 def	0.1333e
P2	Underbridge	0.01333 abcd	0.5000 c	5.427 e	0.5300 h	0.1167ef	0.1600 bcde
P3	Underbridge	0.02667 ab	0.5033 c	5.437 e	0.5067 h	0.1600 d	0.1367de
P4	Underbridge	0.02667 ab	0.5067 c	5.493 e	0.5033 h	0.1467 de	0.1400cde
P1	K/Ala	0.01000 bcd	0.6300 c	6.177 cd	0.6833 g	0.1167 ef	0.1967abcde
P2	K/Ala	0.02000 abc	0.5733 c	6.083 cd	0.7767 f	0.1233 def	0.2067 abcd
P3	K/Ala	0.02000 abc	0.5833 c	6.037 d	0.7933 f	0.1067 f	0.2100 abc

P4	K/Ala	0.01667 abcd	0.5867 c	6.147 cd	0.7233fg	0.1267 def	0.2233 ab
P1	NAKA	0.03000 a	1.0200 b	6.820 b	1.0733 de	0.2300 abc	0.2067 abcd
P2	NAKA	0.02667 ab	1.1167 ab	6.800 b	1.0800 de	0.2567 a	0.1900 bcde
P3	NAKA	0.03000 a	1.1333 ab	6.613 bc	1.0800 de	0.2267 abc	0.1900abcde
P4	NAKA	0.02333 abc	0.7200 c	6.780 b	1.0267 e	0.2433 ab	0.1800abcde
P1	Control	0.00000 d	0.0033 d	0.053 f	0.1133 i	0.0000 g	0.0000 f
P2	Control	0.00000 d	0.0033 d	0.040 f	0.1100 i	0.0000 g	0.0000 f
P3	Control	0.00000 d	0.0033 d	0.053 f	0.0733 i	0.0000 g	0.0000 f
P4	Control	0.00000 d	0.0033 d	0.063 f	0.0900 i	0.0000 g	0.0000 f
L. S. D (0.01)		0.01510	0.2350	0.5172	0.06723	0.01668	0.06105
F pr.		0.389	0.366	0.829	0.026	0.380	0.975

IV. STATISTICAL ANALYSIS OF RESULT

Effects of sites on the uptake of metals by plant

Effects of sites on the uptake of metals by plant are as shown in Table 1 using the Duncan new multiple range test (DNMRT) shows clearly taking for example As having these alphabet b, b, b, a and c implies that there no significant difference between S1, S2 and S3 but there's significant difference between S4 and S5 and between S4, S5 and S1, S2, and S3. All metals uptake showed significant difference with sites, for As with LSD of 0.00755 shows that the effects of these dumpsites on the uptake of heavy metals by plants is not significantly different because all the dumpsite had the same effect on the plants while these plants take up As and Zn with LSD of 0.2586 shows that there is significant difference with the way these individual dump site affect the uptake of Zn by these plants, this applies to all the other interactions in Table 3

Cu was observed to be significantly different in means of S1 and S4 while for S2 and S3 there was no significant difference observed between them. This may be because the type of waste dumped on the sites have similar concentration of copper and also the LSD and F .pr values for Cu were gotten to be0.1175 and <.001 which implies that there's significant difference in the effects of sites on the uptake of metals by plant for Cu since all the different dump site soils had different concentration of the metal which may be because of the types of waste which are been dumped in the various site. It's also noted that all the means from all dump sites are significantly different from that from the control which implies that the heavy metal concentration of these heavy metals on these dumpsites are different in concentration.

Fe was observed to be significantly different in means for all sites, this may be because the type of waste dumped on the both site have different concentration of Fe and also the LSD and F .pr values for Fe were gotten to be 00.2586 and <.001 which implies that there's significant difference in the effects of sites on the uptake of metals by plant for Fe since all the different dump site soils had different concentration of the metal which may be because of the types of waste which are been dumped in the various site. It's also noted that all the site means effects are significantly different from the control.

Pb was observed to be all significantly different in means while S1 and S3 showed no significant difference same effects was observed for S3 and S4 , this may be because the type of waste dumped on the both site have different concentration of Pband also the LSD and F .pr values for Iron were gotten to be 00.2586 and <.001 which implies that there's significant difference in the effects of sites on the uptake of metals by plant for Pb since all the different dump site soils had different concentration of the metal which may be because of the types of waste which are been dumped in the various site. It's also noted that all the site means effects are significantly different from the control.

Zn was observed to be significantly different in means in all the sites , this may be because the type of waste dumped on the both site have different concentration of Zn and also the LSD and F .pr values for Iron were gotten to be 0.03052 and <.001 which implies that there's significant difference in the effects of sites on the uptake of metals by plant for Zn since all the different dump site soils had different concentration of the metal which may be because of the types of waste which are been dumped in the various site. It's also noted that all the means from all dump sites are significantly different from that from the control which implies that the heavy metal concentration of these heavy metals on these dumpsites are different in concentration.

Aswas observed to be not significantly different in all the sites and also the LSD and F.prvalues for As were gotten to be 0.00675and 0.520 which implies that there's no significant difference in the effects of plants on the uptake of the metal by these plant.

Effects of plants on the uptake of metals by plant

Using the Duncan multiple range test Table 2showsthe levels of significant differences in means by all the plants a, a, a, a and a, for P1, P2, P3 and P4 for Cr. This can be observed on this table also for the other interactions.

Cr from Table 2 was observed that using the LSD, and F.prvalue for Cr were gotten to be 0.01492 and

0.733 which implies that there's no significant difference in the effects of plants on the uptake of metals by plant for Cr, these Plants soils have similar abilities of taking up Cr this agrees with the Duncan Multiple range test.

Cu was observed to be non-significantly different in means by all the plants, this may be because these plant have similar abilities of heavy metals up take for Cu and also the LSD and F .pr values for Cu were gotten to be 0.1051and 0.172 which implies that there's no significant difference in the effects of plants on the uptake of metals by plant for Cu, these Plants soils have similar abilities of taking up Cu.

Fe was observed that to be non significantly different in means, this may be because these plant have similar abilities of heavy metals up take for Fe and also the LSD and F .pr values for Fe were gotten to be 0.2313and 0.943 which implies that there's no significant difference in the effects of plants on the uptake of metals by plant for Fe, these Plants soils have similar abilities of taking up Fe.

Pb was observed to be non-significantly different in means, this may be because these plant have similar abilities of heavy metals up take for Fe and also the LSD and F .pr values for Pb were gotten to be 0.02730and 0.893 which implies that there's no significant difference in the effects of plants on the uptake of metals by plant for Pb, these Plants soils have similar abilities of taking up Pb.

Zn was observed to be significantly different in uptake by P1 and P2, but significantly not different in means, P1, P3 and P4, this may be because these plant have similar abilities of heavy metals up take for Zn same thing applies to P2, P3 and P4, also the LSD and F .pr values for Zn were gotten to be 0.0.03007and0.110 which implies that there's no significant difference in the effects of plants on the uptake of metals by plant for Fe, these Plants soils have similar abilities of taking up Zn.

Effects of the interactions between plants and sites on the uptake of metals by plant

Using the Duncan multiple range test to interpret the uptake of Asimplies there's no significantly different in means by all the plants abc, abc, abcd, abc, cd, abcd, ab, ab, bcd, abc, abc, abcd, a, ab, a, abc, d, d, d, and d, for P1S1, P2S1, P3S1, P4S1, P1S2, P1S2, P2S2, P3S2, P4S2, P1S3, P2S3, P4S3, P4S4, P2S4, P4S4, P1S5, P2S5, P3S5, and P4S5 which interprets effects of the interactions between plants and sites on the uptake of metals by plant shown in Table 3not significantly different in means for the interaction of sites and plants in. This may be because these plant site effect have similar abilities of heavy metals up take for As except for S5 which has no presence of AS, also the LSD and F .pr values for As were gotten to be 0.01510 and 0.389 which implies that there is significant difference in the effects of interaction of sites plants on the uptake of metals by plant for As.

The interactions between all the Plants (P1, P2, P3 and P4) in S1 and S4 for Cr were not significantly different in means but are significantly different from S2, S3 and S5. This may be because these plant site effect have similar abilities of heavy metals up take for Cr except forS2, S3 and S5, also the LSD and F .pr values for Cr were gotten to be 0.01668 and 0.01668 which implies that there is significant difference in the effects of interaction of sites plants on the uptake of metals by plant for Cr.

The interaction between all the Plants (P1, P2, P3 and P4) for Cu in all the sites and were also not significantly different for the interaction of sites and plants in S2, S3 and S4 but significantly different from S5. This may be because these plant site effect have similar abilities of heavy metals up take for Cu except for S5, also the LSD and F .pr values for Cu were gotten to be 0.2350and 0.366 which implies that there is significant difference in the effects of interaction of sites plants on the uptake of metals by plant for Cu.

The interaction between all the Plants (P1, P2, P3 and P4) for Fe in all the sites and were also not significantly different for the interaction of sites and plants in S4 but are significantly different from S2, S3 and S5. This may be because these plant site effect have similar abilities of heavy metals up take for Fe except for S2, S3 and S5., also the LSD and F .pr values for Fe were gotten to be 0.5172 and 0.829 which implies that there is significant difference in the effects of interaction of sites plants on the uptake of metals by plant for Fe.

The interaction between all the Plants (P1, P2, P3 and P4) for Pb in all the sites but were significantly different for the interaction of sites and plants in S2, S3, S4 and S5. This may be because these plant site effect have different abilities of heavy metals up take for Pb in S2, S3 and S5., also the LSD and F .pr values forPb were gotten to be 0.06105 and 0.975 which implies that there is significant difference in the effects of interaction of sites plants on the uptake of metals by plant for Pb.

The interaction between all the Plants (P1, P2, P3 and P4) for Zn in S1, S2, S3 and S4, are significantly different in means except S5 which is not significantly different, and are significantly different for the interaction of sites and plants in S2, S3, S4 and S5. This may be because these plant site effect have different abilities of heavy metals up take for Zn in S2, S3 and S5, also the LSD and F .pr values for Zn were gotten to be 0.06723and 0.026 which implies that there is significant difference in the effects of interaction of sites plants on the uptake of metals by plant for Zn.

V. CONCLUSION

Plants are known to take up and accumulate trace metals from contaminated soil (Opaluwa*et al.*,2012) hence detection in plant leaves and crop samples was not surprising. Although the levels of these metals are within normal range for plants, however continual consumption could lead to accumulation and adverse health implication particularly for Pb, As, and Cr (OpaluwaandUmar, 2010). Also the variation in values obtained for these heavy metals in the soil and crop plant samples as against those from control sites is an indication of their mobility from the dumpsites to the farmlands around particularly through leaching and runoffs. This is in agreement with the report of Oluyemi*et al.*,(2008).

Some selected hyper-accumulants also known as bio-accumulant were used to remediate these soils from the various dumpsite, Based on information's from previous studies, their ability to take up these heavy metals, Water leaf, Amaranthus (white seed), Amaranthus(black seed) and Pumpkin were tested for remediation potential of dumpsites. It was observed from the study that water leaf was able remediate up to 47% of Iron mean concentration from UAM road dumpsite. Thus water leaf is considered a good for remediation of soils contaminated with heavy metal. Amaranthus (white seed) was able remediate up to 39.5% of Zinc mean concentration from Underbridge dumpsite. Amaranthus (white seed) is considered a good for remediation of soils contaminated with heavy metal. Amaranthus (Black) was able remediate up to 48.5% of Copper and 39.9% of lead mean concentration from K/Ala street dumpsite. Amaranthus (Black seed) is considered a good for remediation of soils contaminated with heavy metal. Pumpkin was able remediate up to 48% about 40% Arsenic and about 61% of chromium mean concentration from Naka Road dumpsite. Pumpkin is considered a good for remediation of soils contaminated with heavy metal.Tracesof heavy metals from selected dumpsites around Makurdi Metropolitan was established at varying concentrations and this could be as a result of the type of waste that are been dumped at these sites. Qualitative and quantitative analysis for heavy metals presence on soils from four dumpsites reviled As, Cr, Cu, Fe, Pb and Zn which were the identified metals at different concentration.

The concentration of heavy metals determined were in this order Fe> Zn > Cu >Pb> Cr > As in soil samples from K/Ala Dumpsite and Fe> Zn > Cu >Pb> Cr > As in soils samples Underbridge dumpsite, Fe> Cu > Zn >Pb> Cr > As in soil sample from UAM road Dumpsite, and Fe> Cu > Zn >Pb> Cr > As in soil sample from Naka Road dumpsite. Although these metals were found in soils in these dump sites, it is worthy of note that they were below WHO permissive levels. Also continuous usage of these Dumpsites for growing crops could lead to bioaccumulation of these metals and their eventual entry into the food chain with the associated health risks being manifested.

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