EDTA Assisted Uptake, Accumulation and translocation of the Metals: Cu, Cd, Ni, Pb, Se and Zn by *Eleusine indica* L. Gearth from Contaminated Soil.

[1]Garba*, S. T., [1]Santuraki, A. H. and [2]Barminas, J. T.

1 Department of Chemistry, P. M. B. 1069. University of Maiduguri, Borno State. Nigeria.
2 Department of Chemistry, P. M. B. 2076. Federal University of Technology Yola (FUTY), Adamawa State, Nigeria.
stelagarba@yahoo.com

Abstract: The growth of high biomass crops facilitated by optimal addition of EDTA as an enhancement has been considered as an alternative to improve phytoremediation of soils contaminated by heavy metals. In this study, the natural and EDTA assisted ability of *Eleusine indica* to absorb, accumulate and translocate the metals: Cu, Cd, Ni, Pb, Se and Zn were evaluated. Laboratory pot experiments were conducted. One kilogram of the experimental soils of known chemical composition, treated with uniform rate of EDTA (2.7 mmol/kg soil) was placed in plastic pots. Viable seeds of the grass were seeded into the pots and nurtured for a period of 12-16 weeks. The preliminary level of: Cu, Cd, Ni, Pb and Zn in the soil, root and the shoot of the grass was determined using ICP-AOS for Pb and x-ray spectroscopy for rest. The results obtained show that, Cu, Cd, Ni, Pb and Zn has; 164.2, 4.3, 176.4 24.7, 809 and 27.1 respectively in the root, the soil has; 104.5, 5.1, 51.7, 14.4, 180.0 and 12.5 respectively while the shoot has; 654.4, 36.9, 60.7, 46.5, 111.5 and 2.9 for Zn, Se, Pb, Ni, Cu and Cd respectively. At the end of the experiment, the root and shoot of the experimental grass was treated and analyzed for the post experimental level of the metals. The result indicates high levels of Zn, Ni, Cu, Cd and Pb in the order; Zn>Ni>Cu>Cd>Pb: 3550.5, 405.0, 316.8, 112.3 and 96 µg/g respectively was observed in the root. This result is in agreement with the enrichment coefficient (EC) observed: 4.22, 3.64 and 1.07 for Pb, Zn and Cu respectively. It therefore suggests that *Eleusine indica* can absorb and accumulate the metals; Cu, Zn, Ni and Cd in the root with efficient translocation of Pb to the shoot. *Eleusine indica* may serve as metal; Cu, Zn, Ni and Cd stabilizer in the soil with possible phytoextraction of Pb.

[Garba, S. T., Santuraki, A. H., Barminas, J. T. EDTA Assisted Uptake, Accumulation and translocation of the Metals: Cu, Cd, Ni, Pb, Se and Zn by *Eleusine indica* L. Gearth from Contaminated Soil. Journal of American Science2011;7(11): 151-159].(ISSN: 1545-1003). http://www.americanscience.org.

Key words: Phytoextraction, Eleusine indica, ethylenediaminetetraacetic acid (EDTA), Copper, Cadmium, Zink and pollution.

1. Introduction

The importance of the study of environmental hazards and their impact on living beings needs no emphasis. For many years, human activities connected to industry, agricultural sludge and sewage disposals, energy production, mineral exploitation and distribution and traffic, etc caused, and still causing, production and storage of dangerous polluting substances. Soil pollutations, includes: heavy metals, pesticides, PCBs, PAHs, radionuclides, acid rains, wasted waters, particles of dust, coal, minerals, pathogenic organisms, etc. Human evolution has lead to immense scientific and technological progress. Global development raises new challenges especially in the field of environmental protection and conservation. Rapid development is being made not only in the field of electronics but also in biological, medical and pharmaceutical applications. However, the over exploitation of the natural resources with short term, fast profit- oriented management systems has severely damaged the environment.

Under the influence of pollutations, massive destruction of the soil occur which lead to the reduction of healthy drinking water, reduction of territory convenient for agricultural use, reduction of terrain convenient for production of healthy and safe food. Many human diseases result from the buildup of toxic metals in soils. Both humans and livestock can be exposed to toxic metals through inhalation of particulate matter in the air as well as direct ingestion of contaminated food, water or dust (Lasat, 2000). Environmental pollution by heavy metals is now a global issue that requires considerable attention. Acute water and soil pollution are consequences that call for rapid and efficient solution.

2. Remediation of Contamination

The cleanup of soil contaminated by hazardous chemical substances is a cost-intensive, technically complex procedure. Immobilization of inorganic contaminant can be used as a remedial method for heavy metal contaminated soils (Mench et al., 1994). This can be achieved by complexing the contaminants, or through increasing the soil pH by liming (Alloway and Jackson, 1991). High pH decreases the solubility of heavy metals in soil. Although the risk of potential exposure to plants is reduced, their concentration still remains unchanged. Plants are especially useful in the process of soil decontamination because they prevent erosion and leaching which can spread the toxic substances to surrounding areas (USEPA, 2001).

Conventionally when an area is contaminated with heavy metals, the area must be excavated and the soil removed to a separate landfilled site. Agriculturally, this physico-chemical technique for soil remediation render the land useless for plant growth as they remove all biological activities, including useful microbes such as nitrogen fixing bacteria, mycorrhizae, fungi, as well as fauna in the process of decontamination (Burns, Rogers and McGhee, 1996).

Nowadays and in most developed countries, the concept of phytoremediation which is the focus of this study, has emerged as a new technology that uses plants for cleaning or decreasing the toxicity of soil, surface water and waste waters contaminated by metals, organic xenobiotics, explosives or radionuclides (Macek et al., 2000). Plants show several response patterns to the presence of potentially toxic heavy metal ions. Most are sensitive even at low concentrations, others have developed resistance and a reduced number of them behave as hyperaccumulators of these toxic metals (Schat et al., 1999). Phytoremediation includes the following technologies: 1) phytoextraction - the use of plants to remove metals from soils and to transport and concentrate them in above-ground biomass; 2) phytostabilization - the use of plants to minimize metal mobility in contaminated soil through accumulation by roots or precipitation within the rhizosphere; and 3) phytovolatilization - the use of plants to turn volatile chemical species of soil metals (Chaney et al., 1997; Garbisu & Alkorta, 2001; McGrath et al., 2002; Lasat, 2002; Ernst, 2005). Bioremediation especially the use of plants has the following advantages low cost, speed of deployment, preservation of natural soil properties, and reliance on solar energy (Zhuang et al., 2007). The success of phytoremediation however depends, upon the selection of plant species and soil amendments that maximize the removal of heavy metals from the top layer of contaminated soil.

3. Metal Uptake by Plants

Plants possess highly specialized mechanisms to stimulate metal bioavailability in the rhizosphere, and to enhance uptake into their roots (Romheld and Marschner, 1986). Root exudates have an important role in the acquisition of several essential metals. For example, some grass species have been documented to exude from their roots a class of organic acids called siderophores (mugeneic and avenic acids), which were found to significantly enhance the bioavailability of soil-bound iron and possibly zinc (Cakmak, 1996 a, b). Metal bioavailability may also be affected by various plant and/or microbial activities. Some bacteria are known to release biosurfactants (e.g., rhamnolipids) that make hydrophobic pollutants more water- soluble (Volkering et al., 1998).). Plants growth promoting rhizobacteria (PGPR) and arbuscullar mycorrhizal fungi (AMF) has been shown to reduce the toxicity of heavy metals by decreasing the bioavailability of toxic heavy metal or increasing the availability of non-toxic heavy metals (Denton, 2007). Both acidification of the rhizosphere and exudation of carboxylates are considered to be very essential targets for enhancing metal accumulation.

Following immobilization, a metal is captured by root cells and are first bound by the cell wall which is an ion exchanger of comparatively low affinity and low selectivity. The uptake of the metal ions has been shown to take place through the action of some secondary transporters such as channel proteins and/or H_+ ion coupled with carrier proteins (Ghosh and Singh, 2005). Once inside the plant, most metals are too insoluble to move freely in the vascular system, they therefore usually form carbonate, sulphate or phosphate precipitates immobilizing them in apoplastic (extracellular) and symplastic (intra cellular) compartments in the plant roots (Salt et al., 1995).

4. Root-to-Shoot Transport

Subsequent to metal uptake into the root, three processes govern the movement of metals from the root into the xylem: sequestration of metals inside the root cells, symplastic transport into the stele and the release of the metals into the xylem (Gaymard, 1998; Bubb and Lester, 1991). The transport of heavy metals from root to shoot has been observed to primarily take place through the xylem via a specialized membrane transport processes (Salt et al., 1995). This membrane, which usually has a large negative resting potential, provides a strong electrochemical gradient for the inward movement of the metal ions. For example, the xylem loading of Ni may be facilitated by binding of Ni to free histidine (Krämer et al., 1996). Since xylem cell walls have high cation exchange capacity (CEC), non-cationic metal-chelate complexers may also be transported across the plasma membrane via such a specialized carrier, as is the case for Fe-phytosiderophore transport in graminaceous species (Cunningham and Berti, 1993). This relative lack of selectivity in transmembrane ion transport may partially explain why non-essential heavy metals can enter cells, even against a concentration gradient. For example, kinetic data has demonstrated that essential Cu^{2+} and Zn^{2+} and nonessential Ni^{2+} and Cd^{2+} ions compete for the same transmembrane carrier (Crowley et al., 1991).

The movement of metal ions in xylem vessels appears to be mainly dependent on transpiration-driven mass flow from the shoot which creates a negative pressure in the xylem that pulls up water and solutes (Salt et al., 1995). Since some weed species have hyperaccumulator properties and they can survive in highly polluted soils and exclude metals from the soil.This research is focused on the possibility of using grass specie to clean up contaminated soils. To increase metal availability and extend practical field application of phytoextraction in the remediation of soils contaminated with heavy metals, the use of complexing agents such as amino polycarboxylic acids for example ethylenediaminetetraacetic acid (EDTA), chelating organic acids (for example citric acid) have been used to desorbs metals from soil matrix into soil solution to facilitate uptake by plants (Wu et al., 1999; Blaylock and Huang, 2000; Jiang et al., 2003). The aim of the present study was to investigate the natural ability and EDTA assisted uptake and phytoextraction of Cd, Cu, Zn, Ni Pb and Se from heavy metal contaminated soils by the use of the grass Eleusine indica popularly known as Goose or bullgrass.

5. Materials and Methods

Sample and Sampling sites

Grass samples were collected, some two kilometres away from Maiduguri Metropolis, opposite Road safety office to be precise, along Gombe road, south western part of the Metropolis (fig. 1). This site had served as a dumping ground when Borno state environmental sanitation board embarked on the general cleaning of the Metropolis. The grass; Eleusine indica was found as one of the grasses that dominated and successfully grew on the site. To get the plant samples fresh, all collections were done in the morning hours. Collection of soil samples was done from the surface to subsurface portion of the soil (0-10cm depth) around the grass roots (Rotkittikhum et al., 2006)

Sample Preparation and Analysis

The butch of the grass sample collected was separated carefully from the soil around the roots to avoid damages to the roots. These were then thoroughly washed and rinsed with deionized water and separated into shoots and roots. These were then dried at 60^{o}C to a constant weight, grounded into fine powder and sieved, ready for analysis. The soil samples collected were equally dried at 60^{o}C to a constant weight, grounded into fine powder, sieved and analyzed (Lombi et al., 2001). Analysis of all the samples for the heavy metals: Cu, Ni, Zn, Pb, Se and Cd were carried out using ICP-AOS following aqua-regia digestion (McGrath and Cunliffe. 1985). And the results obtained are shown in table two.

Pot experiment

Artificial laboratory pot experiments were conducted. Plastic pots were used for the experiment. 0.5-1 kg of experimental soil (fig.1) of known chemical composition was placed into each of the pots. Viable seeds of E. indica were seeded to soil of known chemical composition. EDTA was applied to the soil at a uniform rate (2.7 mmol/kg soil). Experiments were exposed to natural day and night temperatures. Since humidity is one of the factors ensuring the growth of plants and the necessary physiological processes, grass plants were watered every 5 days with 200 ml of deionized water (Lombi et al., 2001). Four replicates for each experiment was conducted for statistical handling and all were randomly arranged. At the end of the experiment, the grasses were harvested, washed and carefully separated into root and shoot, dried at 60^{o}C to a constant weight, grounded into fine powder, sieved with 2mm wire mesh, treated and analyzed as earlier mentioned.

Statistical analysis

All statistical analyses were performed using SPSS 17 package. Differences in heavy metal concentrations among different varieties of the grass were detected using One-way ANOVA, followed by multiple comparisons using Turkey tests. A significance level of ($P \leq 0.05$) was used throughout the study.

6. Result

Table 1:Physicochemical properties of the experimental Soil.

Soil parameters	Values	±S.D.
Clay %	25.90	±1.80
Silt %	21.70	±2.50
Sand %	50.40	±2.80
pH	7.80	±0.10
Organic matter %	4.15	±0.05
Nitrogen %	0.05	±0.02
C EC mol/ 100 gm soil	11.27	±0.76
EC Ms/cm	464	±0.10
Potassium mg/kg	22.73	±2.63
Moisture Content %	34.00	±1.80

Measurements are averages of three replicates ± S.D. (Standard Deviation)
CEC: Cation exchange capacity, EC: Electrical conductivity.

Soil texture was determined by the Bouyoucos hydrometer method. The moisture content of soil was calculated by the weight difference before and after drying at 105 °C to a constant weight. The pH and electrical conductivity (EC) were measured after 20 min of vigorous mixed samples at 1: 2.5:: Solid: deionized water ratio using digital meters [Elico, Model LI-120] with a combination pH electrode and a 1-cm platinum conductivity cell respectively.

Table 2: Preliminary mean concentration (µg/g) of Cu, Cd, Zn, Ni, Pb and Se in soil, roots and shoots of *E. indica*

Sample Element	Root	±SD	Shoot	±SD	Soil	±SD
Cu	164.20	± 2.93	111.50	±1.61	104.50	±1.94
Cd	4.30	±0.88	2.90	±1.94	5.10	±1.03
Zn	809.70	±3.34	654.40	±3.76	180.00	±3.37
Ni	176.40	±3.37	46.50	± 3.06	51.70	±3.61
Pb	24.70a	±2.59	60.70	±2.57	14.40b	±2.09
Se	27.10a	±3.42	36.90	±1.94	12.50b	±1.61

Means with the same letter within a column are not significantly different at (P ≤0.05) according to the Turkey test. Data are presented in mean ±SD (n = 4).

Table 3: Enrichment coefficient (EC) and Translocation factor (TF) of the metals in *E. indica*.

Elements	TF	EC
Cu	0.53	1.07
Ni	0.26	0.29
Zn	0.81	3.64
Pb	2.46	4.22
Cd	0.67	0.57
Se	1.88	2.95

Table 4:Effects of EDTA application on Uptake and Accumulation of ; Cu, Cd, Zn, Se, Ni and Pb by *E. indica*.

Sample Elements	Root	±SD	Shoot	±SD
Cu	316.80	±2.82	137.50	±4.22
Cd	112.30	±2.63	49.20	±3.95
Zn	3550.50	±4.48	926.20	±4.06
Se	63.70	±2.31	37.80	±3.62
Ni	405.00	±2.82	111.30	±3.74
Pb	96.00	±3.22	326.00	±4.26

Means were found significantly different at (P ≤ 0.05) according to the Turkey test. Data are presented in mean ±SD (n = 4).

Textural analysis of the soil classifies the soil as loamy sand. The loamy sand nature of the soil affected the soil water supplying power, rate of water intake, aeration, fertility and ease of tillage. The soil pH of 7.8 is generally within the range for soil in the region. It is within the recommended range for proper growth and efficient uptake of nutrients and compounds from soil. It has the EC of 464mS/cm. The soil had moderately high organic matter content (4.15%) and relatively low cation exchange capacity (CEC) (11.27 meq/100 g). CEC measures the ability of soils to allow for easy exchange of cations between its surface and solutions. The relatively low level of clay and CEC indicate high permeability and leachability of metals in the soil from this site.

The level content of Se observed from the site is 12.50 (µg/g). It has been observed that metal solubility and availability are both dependent on soil characteristics and are strongly influenced by pH and the degree of complexation with soluble ligands (kaschl et al., 2002).). Many fungi and bacteria in soils are capable of reducing inorganic Se, either to elemental or to volatile and non volatile organic compounds. Immobilisation of Se reduces its availability to plants (Arvy, 1993; Arthur et al., 1993; Landberg and Greger, 1994). Cu in soils can be associated with soil organic matter, oxides of iron and manganese oxides, soil silicate clays and other minerals. It has been found that high levels of Cu characterize urban roadsides associated with road traffic (Celik et al. 2005). Maiduguri metropolitan highway road networking has been characterized with high level of the element (Garba et al., 2007).

Cadmium also is considered to be mobile in soils but is present in much smaller concentrations than Zn (Zhu et al., 1999). This could explain why the level of Cd observed in this study was at low concentration as compare to other elements: 5.10, 3.30 (µg/g) (table 2). The content in soil has been dramatically increased from anthropogenic sources such as smelters, agricultural applications of fertilizer and sewage sludge. Thus making it available for plant uptake and subsequent human uptake, cadmium in the environment therefore poses a significant health risk (McLaughlin et al., 1999).The application of peat and manure in contaminated soil increased Cu, Zn, and Ni accumulation by wheat (Schmidt, 2003). Organic matter in soil could effectively increase the activity of metals in soil and improve metal mobility and distribution in soil. Hence the level of the metals observed in the soil of this study (tale 2).

Some heavy metals, such as Cu, Zn and Ni, are essential micronutrients for plants, but are toxic to organisms at high concentrations (Munzuroglu and Geckil 2002). Zn and Cu accumulated in the largest proportions in root tissue. Uptake of contaminants from the soil by plants occurs primarily through the root system in which the principle mechanisms of preventing contaminant toxicity are found. Table two showed the preliminary level of the elements in the soil, root and the shoot of the grass. The concentration of the metals observed in the root and shoot has level of Cu, Se, Ni, Cd, Pb and Zn as 164.20; 27.10; 176.40; 4.30, 24.7and 809.70(µg/g) respectively in the root. The levels observed in the shoot are: 111.5, 2.9, 654.4, 46.5, 60.7, and 36.9 for Cu, Cd, Zn, Ni, Pb and Se respectively. The heavy metals taken up by the grass plant E. indica can be arranged in the following order: Zn> Ni> Cu>Se>Pb>Cd in the root while in the shoot they can be arranged as: Zn>Cu>Pb>Ni>Se>Cd. Several studies have demonstrated that the concentration of metals in plant tissue is a function of the metal content in the growing environment (Grifferty & Barrington, 2000). Most of The elements in this study are found at higher concentration in the root (Zn, Ni, Cu and Se).

The high level and poor or low translocation of the elements to the shoots could be due to sequestration of the elements in the vacuoles of the root cells to render them non-toxic which may be a natural toxicity response of the grass plant. It has been reported that one of the mechanisms by which uptake of metal occurs in the roots may include binding of the positively charged toxic metal ions to negative charges in the cell wall (Gothberg et al., 2004). The big difference between root and shoot concentrations indicates an important restriction of the internal transport of Cu, Cd, Ni and Zn from roots to shoot, resulting in higher root concentrations rather than translocation to shoots. Low transport of these metals to shoot may therefore be due to saturation of root metal uptake, when the internal metal concentrations are high. The accumulation and level of the elements in either the roots or shoots of the grass plant does not actually read the hyperaccumulating potential. It is the metal transfer coefficients in term of enrichment coefficient or translocation factor that determines the hyperaccumulating potentials of plant specie under experiment.

7. Metal transfer coefficients

Table two shows the metal transfer factors EC and TF by the grass plant. The grass is observed based on table two, efficient to absorb, accumulate and translocate more than one heavy metal from the soil. Soil-to-plant transfer ratio is an important component of phytoextraction. Translocation factor, (TF) defined as the ratio of a metal concentration in plant shoots to that in the roots, may be used to evaluate the effectiveness of a plant to transfer metals from roots to shoots. And the enrichment coefficient EC, given as the ratio of the metal concentration in plant shoots to the observed concentration in soil could be used to express the effectiveness of plant to desorb and accumulates metal in the root (Frissel, 1997). The enrichment coefficient and translocation factor varies between plant to plant and from one element to another.

The enrichment coefficient and translocation factor varies between plant to plant and from one element to another. The EC values of Cu, Zn and Se were found greater than one (1) as compared to other metals (Cd, Ni, Cu and Zn). Enrichment coefficients were a common important factor when considering the potential of phytoremediation of a given species (Zhao et al., 2003). The EC value of greater than one indicated the phytoremediation potential of these heavy metals by the grass plant. This indicates the poor translocation of the elements: Cu, Cd and Ni, to the aerial or above ground part of the grass plant. With the exception of Se all the elements (Cu, Ni, and Cd) has the transfer factor TF less than one. Hence the high level of Cu, Ni, Se, and Cd observed in the root of the grass (table 2).

8. Uptake, Accumulation and Translocation Response to EDTA Application

Most metals in soils exist in unavailable forms, thus soil conditions have to be altered to promote phytoextraction since the phenomenon, depends on a relatively abundant source of soluble metal for uptake and translocation to shoots. Ethylenediaminetetraacetate (EDTA) is probably the most studied, effective amendment in phytoextraction research. Huang et al. (1997) showed that EDTA was the most efficient chelator for inducing the hyperaccumulation of Pb in pea plants shoots, a naturally Pb excluder. Blaylock et al. (1997) demonstrated that the ability of soil-applied EDTA to increase metal uptake in a multi-contaminated soil is not limited to Pb alone. EDTA has also been found to efficiently increase Cd, Cu, Ni, and Zn concentrations in shoots of Brassica juncea. In contrary (Lombi et al,. 2001) observed that EDTA increased metal mobility in soil and uptake by roots, but did not substantially increase the transfer of metals (Cd, Zn, Pb, Cu) to corn shoots. For that, they suggested that EDTA was far more efficient in overcoming the diffusion limitation of metals to the root surface than the barrier of root to shoot translocation. In this research work root heavy metal uptake was greater than shoot heavy metal translocation. Application of EDTA has significantly increased the levels of Cu, Ni, Se, Cd, Pb and Zn concentration in shoots and roots of the grass plant E. indica. As expected, the level of the metals measured in the root and shoot of grass grown on EDTA chelated soil was higher than in the preliminary results (table 4 and 2). Most accumulation of the elements was observed in the roots of the grass plant. The uptake and accumulation of the metals is in the order: Zn> Ni> Cu>Se>Cd. The Cd content in roots was also generally much higher in all species tested than the contents of the shoots, probably because of Cd binding to the root cell walls.

9. Discussion

Phytoextraction efficiency is related to both plant metal concentration and dry matter yield. Thus, the ideal plant species to remedy a contaminated site should be a high yielding crop that can both tolerate and accumulate the target contaminants. For this reason, grasses are the most commonly evaluated plants (Ebbs and Kochian, 1998; Shu et al., 2002). Once accumulated, metal ions enter the root where they can be stored or translocated to the shoot via the transpiration stream (Ximenez-Embun et al., 2001). EDTA application to soil not only increased heavy metal availability in soils but also enhanced heavy metal content of the plant organs. This situation can be explained partly by their chelating capacity (Zhang and Schmidt 2000, Evangelou and Marsi 2001, Zhang et al. 2003). When EDTA was added to soil containing heavy metals (Cu, Cd, Pb, Se and Zn), EDTA complex the soluble form of heavy metal. Chelating agent not only facilities heavy metal removal from the soil via plant uptake; it theoretically means that any metal that can be chelated and solubilized can be removed in the same manner, providing that the soil chemistry favors the forming of a chelate metal complex. In this study application of EDTA has significantly ($p < 0.05$) increased the Cd, Cu, Se, Ni and Zn concentration in the roots of E. indica (table.3). And no signs of toxicity were observed on the shoot with high levels of these elements although EDTA was uniformly applied.

10. Conclusion

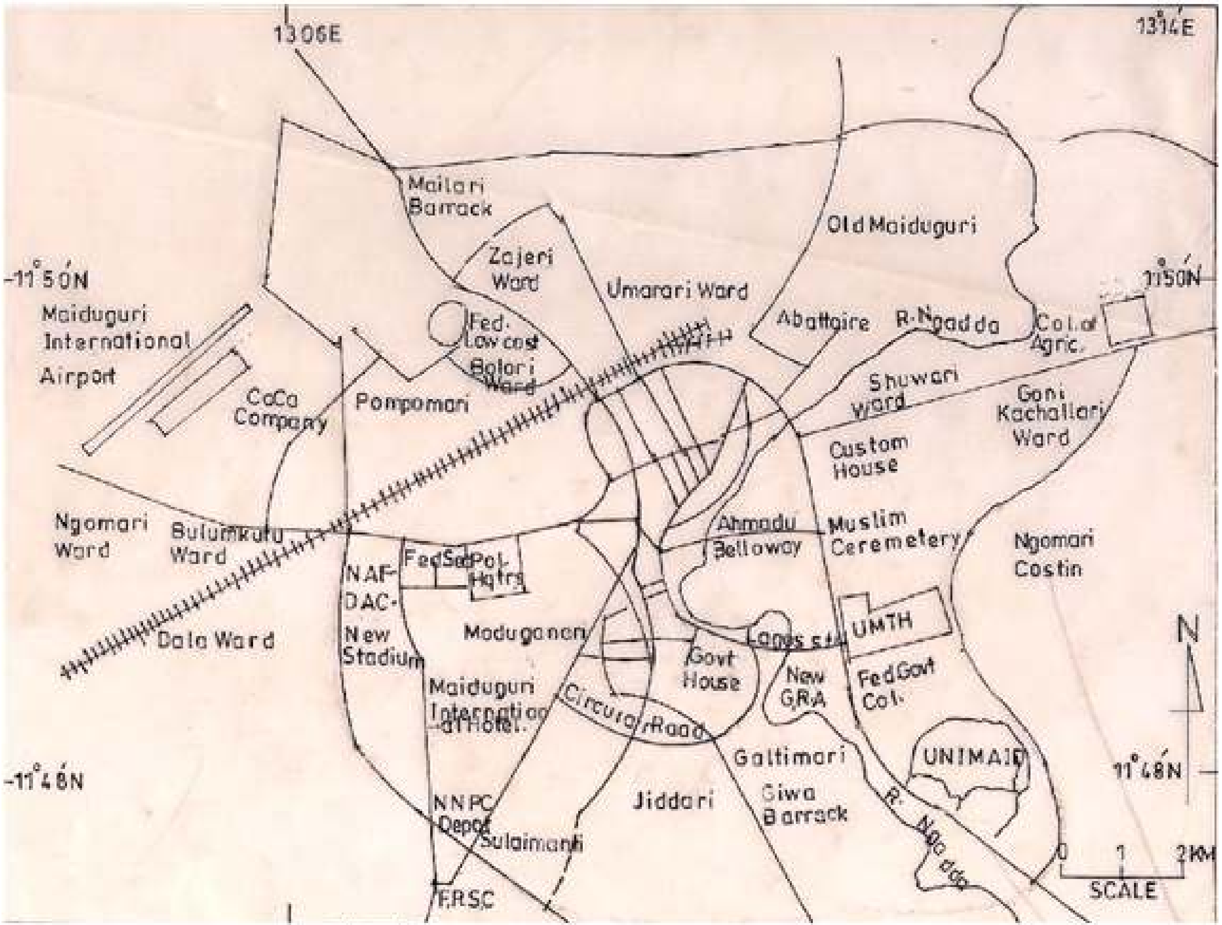
In the present research work, the grass plant E. indica efficiently took up five different heavy metals naturally from soil mainly by roots. The order of uptake of heavy metals was: Zn> Ni> Cu>Se>Cd. The large surface area of fibrous roots of the grass and intensive penetration of roots into the soil could reduce leaching and erosion via stabilization of soil. The plant is further capable of immobilizing and concentrating heavy metals in the roots.

The EDTA-assisted phytoextraction by the grass plant E. indica has been to remove adequate quantities of heavy metals from the contaminated soil and it would therefore be an appropriate remediation technique for the soil. This study provides a promising start for biomass-based phytoextraction; it includes high biomass production species, and growing these species is practically easier than the production of hyperaccumulators.

Goose or bullgrass as it is popularly known, with its distinctive characteristics like higher biomass, fast growth and strong fibrous root system is thus proven to be an ideal plant for phytostabilization, which is an economical, effective, pleasing, and environmentally compatible technology for heavy metals exclusion from contaminated sites.

Acknowledgement:
We are sincerely grateful to Mr. Fine Akawu, the laboratory technologist who relentlessly assisted in the preparation of chemicals and the successful watering of the plants.

*Corresponding address:
Department of Chemistry, P. M. B. 1069. University of Maiduguri,
Borno State. Nigeria.
Email Address: stelagarba@yahoo.com
Gsm № +234070 30352060



KEY: ★ =Sampling site ★★★

Figure 1: Maiduguri Township, showing sampling site.

Reference
1. Alloway BJ, Jackson AP. The behaviour of heavy metals in Sewage sludge amended soils. Sci. Total Environ. 1991: 100: 151-176.
2. Arthur MA, Rubin G, Woodbury PB, Weinstein LH. Plant and Soil. 1993: 148: 83.
3. Arvy MP. Selenate and Selenite uptake translocation in Bean Plants (Phaseouslus vulgaris). Journal of Experimental Botany. 1993: 44: 1083-1087.
4. Blaylock MJ, Salt DE, Dushenkov S, Zakharova O, Gussman C. Enhanced accumulation of Pb in Indian mustard by soil-applied chelating agents. -Environ Sci. Technol. 1997:31: 860-865.
5. Blaylock MJ, Huang JW. Phytoextraction of metals. In: Raskin, I., Ensley, B.D. (Eds.), Phytoremediation of Toxic Metals: Using Plants to Clean up the Environment. - John Wiley and Sons, New York. 2000: pp. 53-70.
6. Bubb JM, Lester JN. The Impact of Heavy Metals on Lowland Rivers and the Implications for Man and the Environment. Sci. Total Env. 1991:100: 207-233.

7. Burns RG, Rogers S, McGhee I. In Contaminants and the Soil Environment in the Australia Pacific Region. (ed. Naidu, R., Kookana, R. S., Oliver, D. P., Rogers S. and McLaughlin M. J.). Kluwer Academic Publishers, London. 1996:pp. 361-410.
8. Cakmak I, Ozturk L, Karanlik S, Marschner H, Ekiz H. Zinc-efficient wild grasses enhance release of phytosiderophoeres under Zn deficiency. J. Plant Nutr. 1996a:19: 551-563.
9. Cakmak I, Sari N, Marschner H, Ekiz H. Kalayci M. Phytosiderophore release in bread and durum wheat genotypes differing in zinc efficiency. Plant Soil. 1996b:180: 183-189.
10. Celik A, Kartal AA, Akdogan A, Kaka Y. Determining the heavy metal pollution in Denizli (Turkey) by using Robinio pseudo-acacia L. Environ Int. 2005: 31:105-112
11. Chaney RL, Malik M, Li YM, Brown SL, Brewer EP, Angle JS, Baker AJM. Phytoremediation of soil metals. Current Opinion in Biotechnology. 1997: 8: 279-284.
12. Crowley DE, Wang YC, Reid CPP, Szansiszlo PJ. Mechanism of iron acquisition from siderophores by microorganisms and plants. - Plant and Soil. 1991: 130: 179-198.
13. Cunningham SD, Berti WR. Remediation of Contaminated Soils with Green Plants: An Overview. In Vitro Cell. - Dev. Biol. 1993: 29: 207-212.
14. Denton B. Advance phytoremediation of heavy metals Using Plant Growth Promoting Bacteria and Fungi.MMG.445 Basic Biotechnology Journal. 2007:3: 1-5.
15. Ebbs SD, Kochian LV. Phytoextraction of zinc by oat (Avena sativa), barley (Hordeum vulgare), and Indian mustard (Brassica juncea). Environmental Science and Technology. 1998: 32: 802-806.
16. Evangelou VP, Marsi M. Composition and metal ion complexion behaviour of humic fractions derived from corn tissue. Plant Soil. 2001: 229: 13-24.
17. Ernst, WHO. Phytoextraction of mine wastes - options and impossibilities. Chemie der Erd, 2005:65: 29-42.
18. Frissel M. Protocol for the experimental determination of the soil to plant transfer factors (concentration ratios) to be used in radiological assessment models. UIR Newsletter. 1997: 28: 5-8.
19. Garba ST, Ogugbuaja VO, Samali A. Public Health and The Trace Elements: Copper (Cu), Chromium (Cr) and Cobalt (Co) in Roadside Dust in Maiduguri Metropolis. Journal of Health, Education, Sport and Sciences (JOHESS). 2007:Volume 6(1):152 - 157.
20. Garbisu C, Alkorta I. Phytoextraction: a cost-effective plant-based technology for the removal of metals from the environment. Bioresource Technology. 2001:77: 229-236.
21. Gaymard F. Identification and disruption of a plant shaker-like outwar channel involved in K+ release into the xylem sap. - Cell. 1998: 94: 647-655.
22. Ghosh M, Singh SP. A comparative study of cadmium phytoextraction by accumulator and weed species. - Environment Pollution. 2005:133: 365-371.
23. Gothberg A, Greger M, Holm K, Bengtsson BE. Influence of nutrient levels on uptake and effects of mercury, cadmium, and lead in water spinach. J. Environ. Qual. 2004:33: 1247- 1255.
24. Grifferty A, Barrington S. Zinc uptake by young wheat plants under two transpiration regimes. J. Environ. Qual. 2004:29:443-446.
25. Huang JW, Chen J, Berti WR, Cunningham SD. Phytoremediation of lead contaminated soils-Role of synthetic chelates in lead phytoextraction. - Environmental Science and Technology. 1997: 31: 800-806.
26. Jiang XJ, Luo YM, Zhao QG, Baker AJM, Christie P, Wong MH. Soil Cd availability to Indian mustard and environment risk following EDTA addition to CD contaminated soil. Chemosphere. 2003: 50: 813-818.
27. Kaschl A, Römheld V, Chen Y. Cadmium Binding by Fractions of dissolved Organic matter and Humic substances from Municipal Solid waste compost. Journal of Environmental Quality. 2002: 31: 1885-1892.
28. Krämer U, Cotter-howells JD, Charnock JM, Baker AJM, Smith JAC. Free histidine as a metal chelator in plants that accumulate nickel. Nature. 1996:379: 635-638.
29. Landberg T, Greger M. Influence of selenium on uptake and toxicity of copper and cadmium in pea (Pisum sativum) and wheat (Trifolium aestivum). Phvsiologia Plantarum. 1994: 90: 637-44.
30. Lasat MM. Phytoextraction of metals from contaminated soil: A review of plant/soil/metal interactionand assessment of pertinent agronomic issues, J. Hazard. Subst. Res., 2000:2: (5-1)-(5-25).
31. Lasat MM. Phytoextraction of toxic metals: a review of biological mechanism J. Environ. Qual. 2002:31: 109-120.
32. Lombi E, Zhao FJ, Dunham SJ, McGrath SP. Phytoremediation of Heavy metal contaminated soils: natural hyperaccumulation

versus Chemically -enhanced phytoextraction. Journal of Environmental Quality. 2001:30: 1919-1926

33. Macek T, Mackova M, Kas J. Exploitation of plants for the removal of organic environmental remediation. Biotechnology Advances. 2000: 18: 23-34.
34. McGrath SP, Zhao FJ, Lombi E. Phytoremediation of metals, metalloids, and radionuclides. Advances in Agronomy. 2002:75: 1-56.
35. McLaughlin MJ, Parker DR, Clarke JM. Metals and mironutrients-food safety issues, Field Crops Res., 1999:60: 143-163.
36. Mench MJ, Didier VL, Loffler M, Gomez A, Masson P. J. Environ. Qual. 1994:23: 785-792
37. Munzuroglu O, Geckil H. Effects of metals on seed germination, root elongation, and coleoptile and hypocotyls growth in Triticum aestivum and Cucumis sativus. Arch. Environ. Cont. Tox. 2002: 43: 203-213.
38. Romheld V, Marschner H. Mobilization of iron in the rhizosphere of different plant species. Adv. Plant Nutr. 1986:2:155-20
39. Rotkittikhum P, Kroatrachue M, Chaiyarat R, Ngernsansaruay C, Pokethitiyook P, Paijitprapaporn A, Baker AJM. Utake and Accumlation of Lead by Plants from Ngam Lead Mine Area in Thailand. Environ. Pollution. 2006:144: 681-688.
40. Salt DE, Blaylock M, Nanda Kumar PBA, Dushenkov BD, Ensley I, Raskin I. Phytoremediation: A novel strategy for the removal of toxic metals from the environment using plants. - Biotechnol. 1995:13: 468-474.
41. Schat H, Llugany M, Bernhard K. Metal specific patterns of tolerance, uptake and transport of heavy metals in hyperaccumulating and non-hyperaccumulating metallophytes. In: N. Terry, G. Barnuelos (eds).phytoremediation of contaminated soils and waters. CRC Press LLC, Boca Raton, F. L., USA. Pp 171-188.
42. Schmidt U. Enhancing phytoextraction: The effect of chemical soil manipulation on mobility, plant accumulation, and leaching of heavy metals. Journal of Environmental Quality. 2003: 32(6): 1939-1954.
43. Shu WS, Xia HP, Zhang ZQ, Lan CY, Wong MH. Use of vetiver and three other grasses for revegetation of Pb/Zn mine tailings: Field experiment. International Journal of Phytoremediation. 2002: 4:47-57.
44. USEPA-United States Environmental Protection Agency. Ground Water Issue. Phytoremediation of Contaminated Soil and Ground Water at Hazardous Waste Sites. 2001. EPA/540/S-01/500
45. Volkering F, Breure AM, Rulkens WH. Microbial aspects of surfactant use for biological soil remediation. Bioremediation. 1998:8: 401-417.
46. Wu, Q. T., Deng, J. C., Long, X. X., Morel, J. L. and Schwartz, C. Selection of appropriate organic additives for enhancing Zn and Cd phytoextraction by hyperaccumulators. Journal of Environmental Sciences, 2006:18(6): 1113-1118.
47. Ximenez- Embun P, Madrid-Albarran Y, Camara C, Cuadrado C, Burbano C, Muzquiz M. Evaluation of Lupinus species to accumulate heavy metals from waste waters. International Journal of Phytoremediation. 2001: 3: 369-379.
48. Zhang X, Schmidt RE. Hormone-containing products' impact on antioxidant status of tall fescue and creeping bent grass subjected to drought. Crop Sci., 2000):40: 1344-1349.
49. Zhang X, Ervin EH, Schmidt RE. Plant growth regulators can enhance the recovery of Kentucky bluegrass sod from heat in Jury. Crop Sci., 2003:43: 952-956.
50. Zhao FJ, Lombi E, McGrath SP. Assessing the potential for Zn and cadmium phytoremediation with the hyperaccumulator Thlaspi caerulescens. Plant and Soil .2003:249: 37-43.
51. Zhu YL, Pilon-Smits EAH, Tarun AS, Weber SU, Jouanin L, Terry N. Cadmium tolerance and accumulation in Indian mustard is enhanced by over expressing glutamylcysteine synthetase. Plant Physiology. 1999:121: 1169-177.
52. Zhuang XL, Chen J, Shim H, Bai Z. New advances in plant growth promoting rhizobacteria for bioremediation. Environment International. 2007: 33: 406-413.

10-24-2011