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Assessing the Phytoremediation Potential of the Grass; C*hrysopogon Aciculatus* for the Heavy Metals: Cr, Co, Cd, Cu, Pb, Zn, Ni and Mn

By Garba, S. T., Idi, A. M. & Baba, A.
University of Maiduguri, Nigeria

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Abstract- Bioaccumulation ability of the grass *Chrysopogon aciculatus* for the heavy metals cobalt (Co), manganese(Mn), copper(Cu), lead(Pb), chromium(Cr), cadmium(Cd), nickel(Ni), and zinc(Zn) was studied. Samples of soil and the grass (fresh) were collected from No. 1 Alu avenue off Ahmad Bello way, Nasarawa L. G. A. of Kano State, Nigeria. Collection was made in August to September, 2015. Samples of the grass collected were washed with tap water, carefully separated into roots and shoots, dried at room temperature to a constant weight and grounded. This was then digested using aqua-regia (HNO_3 and HCl) in the ratio of 1:3 and analyzed for the said metals using AAS. The soil was equally treated using same reagent and analyzed for same metals. The results indicates that levels, of the metals in the soil, can be arranged in increasing order as; Cd < Cu < Zn < Cr < Ni < Mn with Mn having the highest value of 0.0673ppm whereas Cd had the least value of 0.0025ppm. Similarly the levels of the metals in the root ranged between 0.0023 - 0.0159µg/g. Ni in the root has the highest value of 0.0286 µg/g followed by Zn (0.0159ppm), then Mn 0.0154 µg/g. Cd had the least value of 0.0023µg/g. In the shoot, Mn has the highest value of 0.0185 µg/g followed by Ni 0.0126 µg/g then Cr 0.0105 µg/g. Zinc had 0.0094 µg/g followed by Cu 0.0004 µg/g whereas Cd has the least value of 0.0001µg/g. In all the samples analyzed, Pb and Co were found below detection limit. Mn had the translocation factor (TF) value greater than one (1.20). This shows that the grass plant is capable of absorbing and translocating Mn from the soil to the shoot. Hence the value of Mn 0.0185ppm in the shoot was observed to be the highest of all the metals determined in the grass parts. *Chrysopogon aciculatus* therefore may have the ability of remediating soil of excess Mn.

Keywords: soil, grass, roots, shoots, environment, pollution, metals, AAS.

I. Introduction

The quality of life on Earth is linked inextricably to the overall quality of the environment. It is very difficult to define soil quality, as soil composition can vary from place to place. Soil quality is concerned with more than the soil's constituents and composition, but how it functions in a specific environment. The major functions of a soil are generally recognized to include the ability to protect water and air quality, the ability to sustain plant and animal productivity, and the ability to promote human health (Doran and Parkin, 1994; Chen and Mulla, 1999). The release of contaminants into the environment by human activities has increased enormously over the past several decades. The relatively sudden introduction of pollutants into the recipient ecosystems has clearly overpowered their self-cleaning capacity and, as a consequence, resulted in the accumulation of pollutants. Soil pollution by heavy metals is a significant environmental problem worldwide. The various countries confronted with contaminated soil differ considerably in awareness of the problem and in the measure and the technologies to tackle it (Rulkens *et al.*, 1998; Alloway, 1995).

Author α σ ρ: Department of Chemistry, P. M. B. 1069, University of Maiduguri, Borno State, Nigeria. e-mail: stelagarba@yahoo.com

a) Heavy Metal Pollution of Soil

Heavy metal pollution of surface soils due to intense increase in technology, industrialization and urbanization has become a serious concern in many developing countries (Mireles et al. 2012; Wei and Yang, 2010). The accumulation of heavy metals in surface soils is effected by many environmental occurrences which include parent material and soil properties, as well as by human activities, such as industrial production, traffic, farming, and irrigation. Metals are somewhat unique in that they do not undergo either chemically or biologically induced degradation that can alter or reduce their toxicity over time (Knox *et al.*, 2002). The term "heavy metal" is arbitrary and imprecise. Some authors (Raskin *et al.*, 1994), simply, defined "heavy metal" as any element that has metallic properties such as ductility, conductivity, density, stability as cations, ligand specificity, etc. with an atomic number greater than 20. Several metals are essential for biological systems and must be present in a certain concentration range. They provide essential cofactors for metallo-proteins and enzymes and, consequently, too low concentrations lead to a decrease in metabolic activity. At high concentrations however, metals can act in a deleterious manner by blocking essential functional groups, displacing other metal ions, or modifying the active conformation of biological molecules (Collins and Stotzky, 1989). Besides, they are toxic for both higher organisms and microorganisms. Nonessential metals are tolerated at very low concentrations and inhibit metabolic activity at higher concentrations. Large areas of land can be contaminated by heavy metals released from smelters, waste incinerators, industrial wastewater, and from the application of sludge or municipal compost, pesticides, and fertilizers. Irrespective of their sources in the soil, accumulation of heavy metals can degrade soil quality, reduce crop yield and the quality of agricultural products, and thus negatively impact the health of human, animals, and the ecosystem (Jarüp, 2003;Nagajyoti et al., 2010).

b) Decontaminating Heavy Metal Contaminated Soil

Presently, the conventional techniques used to remediate contaminated soils tend to be inefficient (Rock, 1997; McNicoll and Baweja, 1995). Physical removal of contaminated soil and washing of those soils with solvents are expensive, and has met with mixed results (Cookson, 1995). The use of ''bioreactors'' has been attempted, but the contaminated soils must still be brought to the reactor for the cleanup. This process is expensive, and it damages the natural structure and texture of the soil. The various countries confronted with contaminated soil differ considerably in awareness of the problem and in the policies and the technologies to tackle it (Rulkens *et al.*, 1998). Alternatively, in situ bioremediation technique has been attempted; it is a general concept that includes all those processes and actions that take place in order to biologically transform an environment, already altered by pollutants (heavy metals), to its original status. Bioremediation uses primarily microorganisms or microbial processes to degrade and transform environmental contaminants into harmless or less toxic forms. (Garbisu and Alkorta, 2003; Cookson, 1995; Alexander,1999). Microorganisms can detoxify metals by valence transformation, extracellular chemical precipitation, or volatilization. They can enzymatically reduce some metals in metabolic processes that are not related to metal assimilation (Lovley, 1993). Several bacteria couple the oxidation of simple organic acids and alcohols, hydrogen, or aromatic compounds, to the reduction of Fe (III) or Mn(IV). Bacteria that use U (VI) as a terminal electron acceptor may be useful for uranium bioremediation (Lovley, 1993). The reduction of the toxic selenate and selenite to the much less toxic elemental selenium may be exploited for selenium bioremediation (Garbisu et al., 1997). Biomethylation to yield volatile derivatives such as dimethylselenide or trimethylarsine is a well-known phenomenon catalyzed by several bacteria, algae and fungi (White et al., 1997).

c) Phytoremediation

Phytoremediation that uses the remarkable ability of plants to concentrate elements and compounds from the environment and to metabolize various molecules in their tissues appears very promising for the removal of pollutants from the environment (Garbisu and Alkorta 2003). Since most of plant roots are located in the soil, they can play an important role in metal removal via filtration, adsorption and cation exchange, and through plant-induced chemical changes in the rhizosphere (Wright and Otte 1999). There is evidence that plants can accumulate heavy metals in their tissues such as Sebera acuminate and Thlaspi caerulescens (Cunningham and Ow 1996), Arabidopsis thaliana (Delhaize 1996), Typha latifolia, and Phragmites australis (Ye et al. 2001). T. latifolia and P. australis have been successfully used for phytoremediation of Pb/Zn mine (Ye et al. 1997). Metal accumulation by plants is affected by many factors. Variations in plant species, the growth stage of the plants and element characteristics control absorption, accumulation and translocation of metals. Furthermore, physiological adaptations also control toxic metal accumulations by sequestering metals in the roots (Guilizzoni, 1991).

With in the field of phytoremediation, different categories have been defined such as, among others, phytoextraction, phytofiltration (rhizofiltration, blastofiltration), phytostabilization, phytovolatilization, phytodegradation (phytotrans formation), plant-assisted bioremediation (plant-assisted degradation, plant-aided in situ biodegradation, phytostimulation, enhanced rhizosphere degradation, rhizodegradation) (Alkorta et al., 2004). The phytoextraction technique for instance, uses the uptake capabilities of plants, it represents one of the largest economic opportunities for phytoremediation. Plants can accumulate metals that are essential for growth and development (such as Cu, Mn, Fe, Zn, Mo, and possibly Ni) and also some that have no known biological function (Cd, Cr, Pb, Co, Ag, Se, Hg) (Brooks, 1998; Raskin *et al.*, 1994). Plants have been described as solar-driven pumping stations (Cunningham *et al.*, 1995) which can actually remove these contaminants from the environment. As a result, metal removal by vegetation can be greatly enhanced by the judicious selection of plant species. The knowledge about the abilities of different plant species or tissues to absorb and transport metals under different conditions will provide insight into choosing appropriate plants for phytoremediation of the polluted regions. This research work therefore is aimed at assessing the non-amended phytoextraction potential of the native grass; Part Harcourt grass (*Chrysopogon aciculatus)* for the heavy metals: cobalt (Co), manganese (Mn), copper (Cu), lead (Pb), chromium (Cr), cadmium (Cd), nickel (Ni), and zinc (Zn).

d) Sample Collection

The grass plant sample was collected by uprooting gently from the soil. Collection was made in the morning hours in order to get the samples fresh, avoid damages to the plants parts (the roots) and to avoid contamination by other plants specie. The soil around the grass plant was also collected. Soil collection was done using hand trowel from the surface to the sub surface portion of the grass plant at a depth of 0-10cm beneath the root of the grass. Four different samples at three different locations within the same vicinity were collected and pulled together to represent a sample. Samples were collected from, No:1 Alu avenue off Ahmadu Bello way, Nassarawa L.G.A, Kano State, Nigeria, located between the latitude 11º58'37"N 8º33'45"E / 11.97694ºN..

e) Sample Preparation and Analysis

The fresh butches of the grass sample collected were carefully washed with tap water, separated into roots and shoots. These were then dried at room temperature to a constant weight, grounded and sieved using 2mm nylon mesh. To 1.0g of the powdered plant samples placed in an acid washed crucible, 15ml of aqua-regia acid (HNO_3 and HCl) solution in ratio of 1:3 was added. The corresponding solution was heated gently until white fumes had appeared. This was then cooled and 10ml of distilled water was added and heated again in a water bath to insure complete dissolution. The mixture was then filtered into a 50ml volumetric flask using with watt man filter paper No.1. The clear solution was diluted up to the 50ml mark with distilled water. The soil sample was equally digested with same volume of aqua-regia solution using 1.0g of the sieved sample (Radojevic and Bashkin, 1999). Analysis of the samples for the metals: Mn, Zn, Cu, Co, Ni, Cr, Pb, and Cd were carried out using a bulk scientific Atomic Absorption Spectrophotometer (AAS) model NO. AA-6800. Standard working solution of the elements of interest was prepared for standard calibration curve. The concentration of each metal was extrapolated from the standard calibration curve.

f) Statistical Data Handling

All statistical data handling were performed using Excel 2007. Differences in heavy metal concentrations among the different samples were detected using One-way ANOVA. A significance level of ($P \leq 0.05$) was used throughout the study.

g) Results and Discussion

Phytoremediation, the use of plants to extract, sequester, and/or detoxify pollutants, has been reported to be an effective, non-intrusive, inexpensive, environment-friendly accepted technology to remediate polluted soils (Weber et al., 2001). Phytoremediation is widely viewed as the ecologically responsible alternative to the environmentally destructive physical remediation methods currently practiced (Meagher, 2000).

Plants grown in metal-contaminated soils take up metal ions in varying degrees. This uptake is largely influenced by the bioavailability of the metals which is in turn determined by both external (soil-associated) and internal (plant-associated) factors.

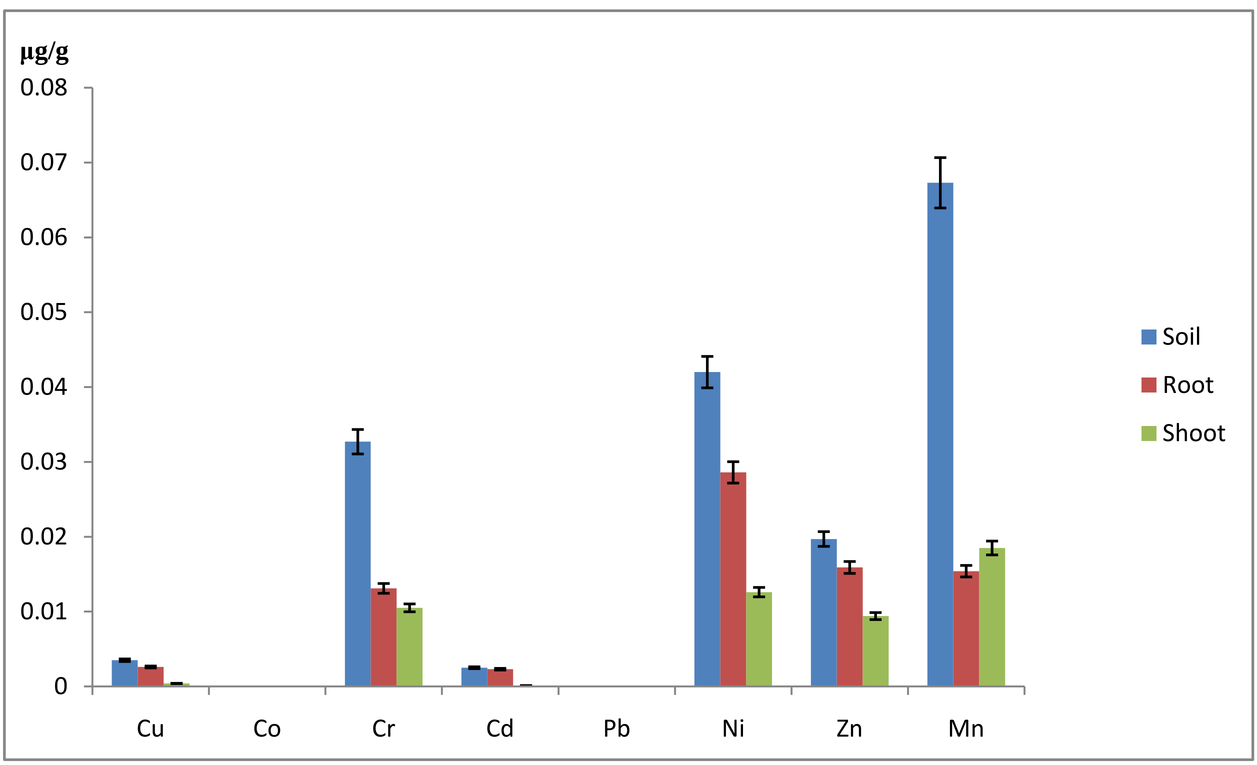

Fig. 1 : Levels (µg/g) of Elements Determined in the Soil, Root and Shoot of the grass

Figure one above gives the levels of the metals; Mn, Zn, Ni, Pb, Cd, Cr, Co, and Cu determined in the soil, roots and shoots of the grass *Chrysopogon aciculatus*. The result obtained indicates that levels of the metals in the soil, can be arranged in increasing order as; Cd < Cu < Zn < Cr < Ni < Mn with Mn having the highest value of 0.0673µg/g whereas Cd had the least value of 0.0025µg/g. Similarly in the grass sample, the levels of the metals in the root ranged between 0.0023 - 0.0159 µg/g. Nickel in the root has the highest value of 0.0286 µg/g followed by Zn (0.0159 µg/g), then Mn 0.0154 µg/g. Cadmium had the least value of 0.0023 µg/g in the shoot, Mn has the highest value of 0.0185 µg/g followed by Ni 0.0126 µg/g then Cr 0.0105 µg/g. Zinc had 0.0094 µg/g followed by Cu 0.0004 µg/g whereas Cd has the least value of 0.0001µg/g. In the entire sample analyzed, Pb and Co were found to be below detection limit.

Plant species differ widely in their ability to accumulate heavy metals. Figure 1 show that, with the exception of Mn, the root of the grass accumulate higher concentrations of metals than shoots, which indicated greater plant availability of the substrate metals, as well as interior limited mobility of the plant. This is consistent with previous observations (Garba et al., 2011; Garba et al., 2012a). Garba et al. (2012b) reported that the concentrations of heavy metals in the root tissues of *penisetum pedicellatum* from polluted areas were usually found to contain higher concentrations of most metals compared to the aboveground parts. Fitzgerald et al. (2003) observed that monocotyledonous species contained higher concentrations of Pb in the roots compared to shoots. In comparison with the ranges of metal concentrations in the soil and in the root, the concentrations of Cu, Cr, Zn and Ni in shoots were maintained at low levels (Fig. 2). The results presented in the study suggest that this metal-tolerating strategy is widely evolved and exists in plant species when they grow in metal-contaminated areas. The elevated metal concentrations in the root and low translocation to the shoot in the grass species examined might also suggest that, the grass may be capable of rather well-balanced uptake and translocation of metals when grown on heavily metal polluted conditions.

h) Chrysopogon aciculatus

Chrysopogon aciculatus (Retz.) Trin. (Fig, 3), is a perennial grass with a creeping rhizome (Paria and Chattopadhyay, 2005). It's culm is divided into creeping base and erect portion. The creeping base is covered with imbricate scale like old sheaths. Sheaths are long, striate, sometimes purple - tinged and imbricate (Singh et al., 2001). Leaf blades are flat. Panicles are reddish purple, narrowly elliptic and long. It is usually found in sunny, dry, exposed areas such as roadsides, lawns, pasture, bank of rivers, water courses, etc (Noltie, 2000). It is a common weed found almost throughout the year. The grass has a potential to spread quickly as the creeping rhizomes grow over open areas. Cattle eat this species in default of anything else. It can tolerate grazing, mowing and trampling by animals (Kabir and Nair, 2009). It is a very good soil binder and so prevents soil erosion. This can be difficult to eradicate if it becomes established (Ambasta and Rana, 2013).

Fig. 3 : Chrysopogon aciculatus (Retz.) Trin

It has been reported that plants for phytoextraction, i.e., metal removal from soil, should have the following characteristics: (i) tolerant to high levels of the metal, (ii) accumulate reasonably high levels of the metal, (iii) rapid growth rate, (iv) produce reasonably high biomass in the field, and (v) profuse root system (Garbisu et al. 2002).

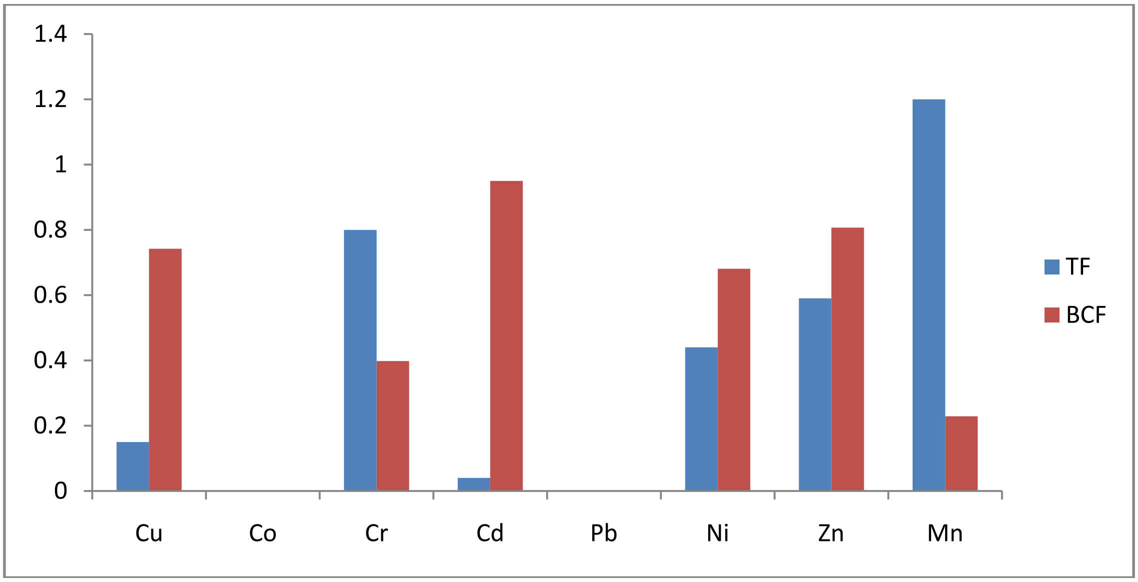

Fig. 2 : Biological Concentration Factor (BCF) and the Translocation Factor (TF)

The translocation factor (TF) which determine the ability of the grass to remediate the soil if its calculated value is one (1.0) or above. It was described as ratio of heavy metals in plant shoot to that in plant root (McGinty, 1996; Moffat, 1995) were found to be less than one for all the metals except Mn which has 1.20. This shows that the grass plant is capable of absorbing and translocating Mn from the soil via the root to the shoot. Hence the value of Mn 0.0185 μg/g in the shoot was observed to be the highest of all the metals determined in the grass plant parts (fig. 2). The grass may also be used in one of the phytoremediation technique; phytostabilization. This is because the level of the metal Ni was found at a higher concentration in the roots although the translocation factor (TF) was found to be less than one (1). Phytostabilization, is referred to as in-place inactivation, is primarily used for the remediation of soil, sediment, and sludges (United State Protection Agency, 2000). It is the use of plant roots to limit contaminant mobility and bioavailability in the soil. The plants primary purposes are to (1) decrease the amount of water percolating through the soil matrix, which may result in the formation of a hazardous leachate, (2) act as a barrier to prevent direct contact with the contaminated soil and (3) prevent soil erosion and the distribution of the toxic metal to other areas (Raskin and Ensley, 2000).

II. Conclusion

Phytoextraction as the name implies is not a magic solution, commercially, it is gaining appeal because it is cheaper than conventional clean-up methods. But it is not an easy technology just consisting of picking up some plants and placing them in the metal polluted area. On the contrary, it is highly technical, requiring expert project designers with plenty of field experience that carefully choose the proper species and cultivars for particular metals (and combinations of them) and regions, and manage the entire system to maximize pollutant removal efficiency.

Form the result obtained and the transfer factor calculated, it shows that the grass plant (C*hrysopogon aciculatus)* may have the ability of phytoextracting excess Mn from polluted soil.

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