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Phytoremediation of Heavy Metals from Flood Plains of Tannery Waste Water Streams in Challawa Industrial Estate- Kano

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Abstract
Phytoremediation refers to the use of green plants to remove, contain or stabilize pollutants. Four plants samples (*sida acuta, cassia obtusifolia, mitracarpus villosus, and ipomoea asarifolia)* were obtained from the flood plain of tannery waste water stream of Challawa industrial estate-Kano and examined for their possible ability to remediate heavy metals such as cadmium, iron, copper, lead and chromium from the soil. This was done by comparing the concentration of these metals in the selected plant samples using Atomic Absorption Spectrophotometer (AAS) with that of the corresponding soil samples from where they were collected. From results obtained, *sida acuta* had equal concentration of the heavy metals analyzed with that of its corresponding soil sample except for iron and lead, while *cassia obtusifolia* accumulated iron and lead to values higher than that of the corresponding soil sample with concentration of 185.25mg/kg and 81.50mg/kg for the plant species in contrast with 139.00mg/kg and 54.25mg/kg respectively for the corresponding soil sample. *Mitracarpus villosus* and *ipomoea asarifolia* showed higher level of absorption of chromium, they posses an accumulation ratio of 2:1 and 4:1 respectively, which indicate their higher accumulative capacity for chromium than other heavy metals. *Ipomoea asarifolia* also showed significantly higher values for lead with concentration of 80.50mg/kg compared to 52.75mg/kg of the corresponding soil sample. *Ipomoea asarifolia, mitracarpus villosus* and *cassia obtusifolia* have showed significant level of absorption for heavy metals such as chromium and lead and can therefore be recommended as accumulators for the remediation of these heavy metals from the contaminated soil of the flood plain in the study area.

1. Introduction

Phytoremediation refers to the use of green plants to remove, contain or render pollutants harmless [1].Research has demonstrated that plants are effective in cleaning up contaminated soil.[2] The capacity of taking up and accumulating heavy metals in organs of plants and the advantage of a large biomass makes it possible to remove heavy metals by phytoremediation in situ.[3] The three mechanism used by plant to remove or stabilized metals from soil and water are; phytoextraction, rhizofiltration and phytostabiilzation, rhizofiltration refers to the absorption into plants roots of contaminant that are in solution surrounding the root zone (rhizosphere), rhizofiltration is used to decontaminate groundwater;.phytostabilzation is the use of perennial, non harvested plants to stabilize or immobilize contaminant in the soil and groundwater while phytoextraction is the process of growing plants in metal contaminated soil, the plant roots then translocate the metals into aboveground portion of the plant [4]. A wide range of inorganic and organic compounds cause contamination, these include heavy metals, combustibles, and putrescible substances, hazardous waste, explosives, and petroleum product, major component contaminant are heavy metals, they present a different problem than organic contaminant, soil microorganism can degrade organic contaminant while metals need immobilization or physical removal. Although many metals are essential, all metals are toxic at higher concentrations, because they cause oxidative stress by formation of free radicals [5]. Another reason why metals may be toxic is that they can replace essential metals in pigments or enzymes, disrupting their function, thus metal render the land unsuitable for plant growth and destroying the biodiversity. [5].

Trace amount of some heavy metals can be detrimental to the organisms, nonessential heavy metals includes arsenic, antimony, cadmium, chromium, mercury, lead etc. these metals are of particulate concern to surface water and soil pollution.[6]

Heavy metals exist in colloidal, ionic particulate and dissolved phase, metals have high affinity for humid acid, organo clays and oxides coated with metallic matter, the soluble forms are generally ions or unionized organometallic chelates or complexes [7]

The solubility of metals in soil and groundwater are controlled by pH, amount of metal, cation exchange capacity, organic content and the oxidation state of the mineral component and redox potential of the system [8]

In general, soil pH, seems to have greatest effect of any single factor on the solubility or retention of metals in soil, with a greater retention and lower solubility of metals cation occurring at high soil pH [9] Immobilization of inorganic contaminant can be used as a remedial method for heavy metal contaminated soils [11]. This can be achieved by complexing the contaminants, or through increasing the soil pH by liming [16].

Plants generally have three basic strategies for growth on metal contaminated soil, they include metal excluders, metal indicators and metal accumulators plant species [10]

Metal excluders prevent metals from entering their aerial part or maintain low and constant metal concentration over a broad range of metal concentration in soil, it mainly restrict metal in their root, the plant may alter its membrane permeability, change metal binding capacity of the cell wall or exudes more chelating substances [11]

Metal indicators are plant species which actively accumulate metals in their aerial tissues and generally reflect metals level in the soil, the tolerate the existing concentration by producing intracellular metal binding compounds (chelators), or alter metal compartmentalization pattern by storing metals in non-sensitive parts [11]

Metals accumulator plant species can concentrate metals in their aerial part, to level far exceeding that of the soil. Hyper accumulators are plant that can absorb high level of contaminant concentration either in their root, shoots and/or leave.[12]

Phytoremediation which make use of vegetation to remove, detoxify or stabilize persistent pollutant is a green and environmentally friendly tool for cleaning polluted soil [3, 11] It involves repeated cropping of plants in contaminated soil, until the metal concentration drops to acceptable level [12]. The ability of the plants to account for the decrease in soil metal concentrations as a function of metal uptake and biomass production play an important role in achieving regulatory acceptance. One of the hurdles for commercial implementation of phytoextraction has been the disposal of contaminated plant material. After each cropping, the plant is removed from the site; this leads to accumulation of huge quantity of hazardous biomass. This hazardous biomass should be stored or disposed appropriately so that it does not pose any risk to the environment.

This main focus of this research report is to find out the mobility, bioavailability of plants and their response to presence of heavy metals in soils and flood plains. The research work also seeks to identify plant species along the waste water stream that are hyper accumulators, the plant would be analyzed for chromium, cadmium, lead, copper and iron, which are among the widely used heavy metal that are released in the waste water stream in Challawa industrial area of Kano state.

2. Methodology

2.1. Sample Collection

Four plant species were selected, based on their biomass as well as their ability to withstand the hazardous condition created in the soil by heavy metal contamination.

The plant were randomly selected within a 50 meters radius of the waste water stream along the flood plains of the Challawa industrial estate of Kano state, soil sample were also collected from each area with a depth of 15cm where the plant sample were collected, the plant species were identified by Botanists from the Department of Biological Sciences, Faculty of Sciences, Bayero University, Kano and were coded as follows:

- Sample A-*sida acuta* (Rai-rai or broom weed)
- Sample B-*cassia obtusifolia* (Tafasa or sickle senna)
- Sample C- *mitracarpus villosus* (Gogamasu)
- Sample D-*ipomoea asarifolia*

2.2. Sample Preparation

Both the plant sample and the soil sample was dried at room temperature for 14 days, sample were washed thoroughly and then pulverized to fine small particles, it was digested with nitric acid using, the approach adopted by

Zheljazkov and Nielson (1996) [13] but with modification.

One gram of sample was placed in a 250ml digestion tube and 10 ml of concentrated HNO_3 was added, the sample was allowed to stand for 18hours at ambient temperature, the sample was then heated almost to dryness when the volume of sample was reduced to about 1ml, 25ml of distilled water was added and solution was boiled for 1minute.

The interior walls of the tube was swirled through out the digestion to keep wall clean and prevent loss of sample, the solution was filtered with what man No 42 filter paper and 0.45µm Millipore filter paper.

2.3. Heavy Metal Analysis

The concentration of chromium, lead, iron, copper and cadmium in the final solution were determined using atomic absorption spectrophotometer.

3. Results and Discussion

3.1. Results

The results of the atomic absorption spectrophotometric analysis of plant and soil samples are presented below;

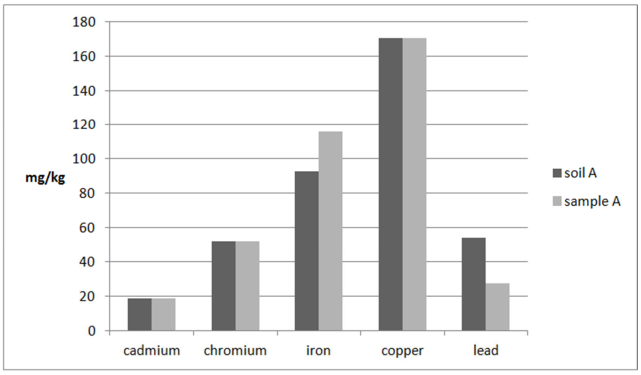

Figure 1. *Heavy metal concentration in soil sample A and plant sample A (sida acuta)*

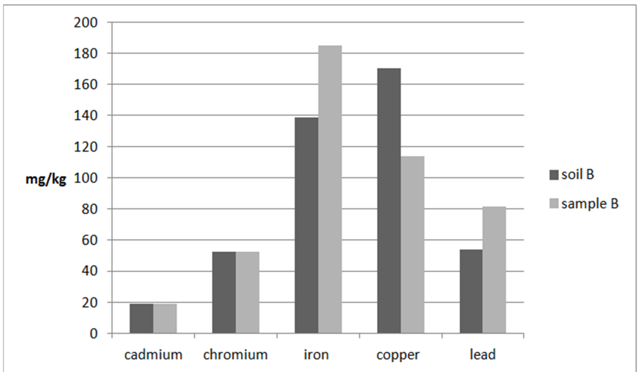

Figure 2. *Heavy metal concentration in soil sample B and plant sample B (cassia obtusifolia)*

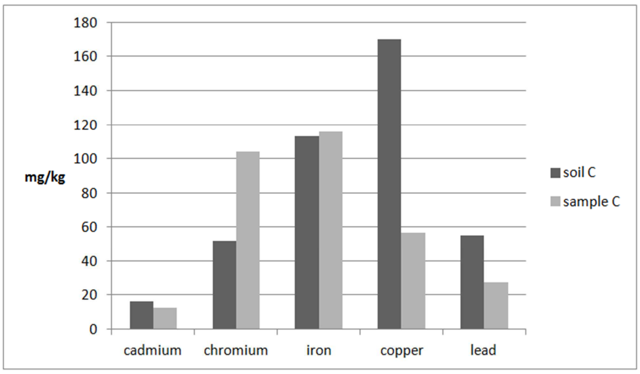

Figure 3. *Heavy metals concentration in soil sample C and plant sample C (mitracarpus villosus)*

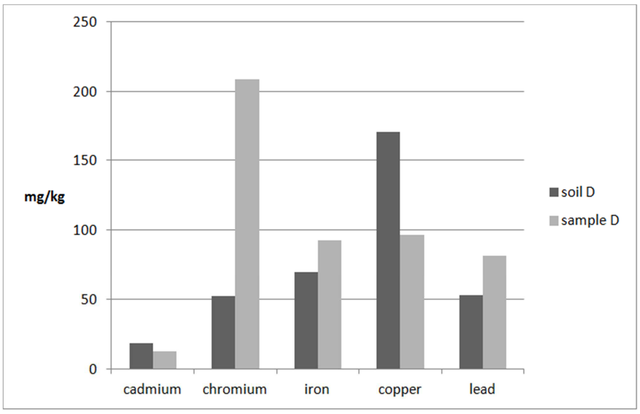

Figure 4. *Heavy metal concentration in soil sample D and plant sample D (ipomoea asarifolia)*

3.2. Discussion

From figure 1 it can be observed that the concentrations of heavy metals such as cadmium, chromium, and copper absorbed by the plant species *Sida acuta* corresponding with that of in soil sample except for iron where it had a higher concentration that the soil sample and lead where it had lower concentration in the plant species than the soil sample. Fig.2 shows that *cassia obtusifolia* was able to accumulate iron and lead to values higher than that of the soil where they were formerly resident with concentration of 185.25mg/kg and 81.50mg/kg compared to 139.00mg/kg and 54.25mg/kg respectively. The concentration of lead in the plant is below that recorded by plants such as *Brassica juncea*, commonly called in dian mustard, which has been found to have a good ability to transport lead from the roots to the shoots. The phytoextraction coefficient for *Brassica juncea* is 1.7 and it has been found that a lead concentration of 500 mg/l is not phytotoxic to *Brassica* species [5]. Sing and Ghosh [12] reported that Ipomoea extracted maximum lead at 200 mg kg^{-1}; *Datura* and *Phragmytes* was best extractor at 100 mg kg^{-1}, whereas Brassica species were remediated lead with concentration of 50 mgkg-1 soil. This means that the species *cassia obtusifolia* used in this study remediated more lead from the soil than plants used by Sing and Ghosh. From results presented in this figure (2), it can also be observed that the concentration of cadmium and chromium in the plant speicies is the same as in the corresponding soil sample where the plant was obtained. The concentration of heavy metals analysed in *mitracarpus villosus* and its corresponding soil sample is shown in figure 3. It can be observed from this result that for cadmium, copper and lead, the concentration of these metals in soil samples is higher than that in the plant species; this means that the plant cannot be used in the remediation of these heavy metals. However the concentration of chromium in the plant species was recorded to be higher than that in the corresponding soil sample therefore the plant species can be used in the remediation of this heavy metal. The concentration of iron can be observed to be slightly higher than its concentration in the soil sample Figure 4 represents the result of heavy metal analysis of plant species *ipomoea asarifolia* and its corresponding soil sample. Form this result it can be observed that of all the heavy metals analysed only cadmium and copper had its concentration higher in the soil sample than in the plant species under investigation. Conversely the plant species was observed to record significantly higher levels of heavy metals with concentration of 208.25 mg/kg, iron 90.3mg/kg, 75.5mg/kg for chromium, iron and lead respectively. This invariably points out that these plant species can be described as hyper accumulators for these heavy metals [17] Researchers have identified hyperaccumulator species by collecting plants from the areas where soil contains greater than usual amount of metals as in case of polluted areas or geographically rich in a particular element [18].

The accumulation ratio usually indicate the accumulation capacity of plants, it is the ratio of the contents of metals in plants or organ to the content of this element in the cultivated solution. [3] The accumulation ratio of these plants with the soil samples with regards to chromium was 2:1 and 4:1 respectively which shows the capacity of the plants to accumulate chromium. The result also reveal that *Ipomoea asarifolia* also had higher level of lead and iron with concentration of 92.50 mg/kg and 81.50mg/kg than their corresponding soil sample which concentration was 70.00mg/kg and 55.00 mg/kg as seen in fig.4.It can also be deduced from this figure that *Ipomoea asarifolia* absorbed chromium with recorded concentration of 225mg/kg. With this high chromium concentration absorbed by *Ipomoea asarifolia*, this species can therefore be regarded as a hyper accumulator as defined by Baker and Brooks [17] In comparative terms, chromium was better remediated by *Ipomoea asarifolia* than all other species used in this study. *Ipomoea carnea* a plant of the same specie as *ipomoea asarifolia has* been reported to effectively extract cadmium, chromium and lead from polluted soils more than the *brassica* species widely regarded as the indicator species [3] Lead was remediated at a lower concentration by this species than that remediated by other plant species used in this study.

The overall result indicates that cadmium had the least concentration in soil samples collected. The concentration of this heavy metal in soil samples was the same as that absorbed by the plant species *mitracarpus villosus* and *Ipomoea asarifolia* as observed Figures 1 and 2.Figure 3 and 4 show that the concentration of cadmium is higher in soil samples than that in the plant species *cida acuta* and *cassia obtusifolia* collected from these sample locations. The amount of Chromium absorbed by *Ipomoea asarifolia* and *mitracarpus villosus* was higher than its concentration in soil samples as can be seen in figures 3 and 4 while the recorded concentrations of this heavy metal in both *sida ocuta* and *cassia obtusifolia* (Figures 1 and 2) is the same as that recorded in their respective soil samples, hence they cannot be said to good plant species in the remediation of chromium from the environment. Iron was observed to be absorbed or remediated by all the plant species being investigated with *mitracarpus villosus* recording the least significant degree of remediation with its corresponding soil sample while *cassia obtusifolia* recorded the highest significant degree of remediation of this metal from the soil.

From Figures 2 – 4 it can be observed that the concentration of copper in soil samples exceeded that in the corresponding plant samples from where they were obtained. However it can be seen in figure 1 that the concentration of the heavy metal is equal in the plant species *cida acuta* and its corresponding soil sample. These results reveal that none of the plant species used in this study can effectively remediate copper from the environment.

Results of analysis of lead in both soil samples and the corresponding plant species collected from the sample locations presented in Figures 1 and 3 shows that thel concentration of this metal is higher in soil samples than in spcies of *cida acuta* and *mitracarpus villosus* thus these plants cannot be used in phytoremediation of lead. However plant species such as *cassia obtusifolia* and *Ipomoea asarifolia* (Figures 2 and 4) was able to absorb the heavy metal from soil from where they were collected thus they can be prescribed as hyper accumulators in phytoremediation

Apart from the fact that these plants are able to accumulate specific heavy metals in their organs to concentration far beyond their concentration in the soil, they can also accumulate other heavy metals with no sign of defect, which suggest that they can also serve as bio indicators and can be used to study geographical pattern of pollutants. [14]

The concentration of cadmium and copper was way above the maximum allowed limit of the heavy metals in soil for different countries; chromium was at the maximum at allowed limit for Great Britain while lead and iron where below the limits set by most countries of the world [15]. These heavy metals analyzed form the bulk of most of the chemical compound used in the tanneries in the Challawa industrial estate –Kano, and are responsible for the high level of these metals and subsequent pollution of the soil in Challawa flood plains.

4. Conclusion

These plant species studied which are indigenous to Challawa flood plain and from results obtained that can accumulate heavy metals especially chromium and lead to level higher than that in the soil, therefore *ipomoea asarifolia,* *mitracarpus villosus and cassia obtusifolia* can be employed to remediate the heavily polluted Challawa flood plains. Botanical studies into cultivation and physiology of these plants, as well as identification and characterization of more plant hyper accumulators species is needed to increase the efficacy of phytoremediation of industrial pollutants from soils in flood plains in Nigeria.

References

[1] Brian, H. Phytoremediation of heavy metals, Cluster 1:biotechnology.COSMOS 2009.web. 31, May, 2013.

[2] Wenzel, W.W., Adriano, D.C., Salt, D, and Smith, R. (1999) Phytoremediation: A plant microbe based remediation system.pp.457-508.In D.C. Adriano et al (Ed).Bioremediation of contaminated soils, American Society of Agronomy. Madison, W.I.

[3] Cheng, S. (2003): Heavy metals in plants and phytoremediation-Environ Science and Pollution Research 10(5); 335-340.

[4] U.S.D.A (2000): Heavy metal soil contamination-soil quality, urban technical report note 3. http//soils.usda.gov/sqi/publication/utn.html

[5] Henry, J.R. (2000): In an overview of phytoremediation of lead and mercury- NNEMS report Washington, D.C.:pp3-9.

[6] Berti, W.R. and Jacobs, L.W., P.(1996) Chemistry and phytotoxicity of soil trace element from repeated sewage sludge application-J. Environ. Qual.25; 1025-1032.

[7] Elliot, H.A., Liberali, M.R. and Huang, C.P.(1986) Competitive adsorption of heavy metals by soils.-J. Environ Qual.15; 214-219.

[8] Cornell, D.W.,G.J., Miller(1984): Chemistry and Eco toxicity of pollution.-John Wiley and sons: NY,pp 444

[9] Basta, N.T, Pantone D.J and Tabatabai, M.A, (1993): Path analysis of heavy metals adsorption by soil-Environmental pollution.107; 153-158.

[10] Raskin, I, Kumar, P.B.A.N., Dushenkov, S. and Salt, D.(1994): Biconcentration of heavy metals by plants-Current Opinion Biotechnology 5;285-290.

[11] Cunningham, S. April 19-22,(1995)In proceeding/Abstracts of the fourteenth annual symposium on current topics in plan Biochemistry,-Physiology and Molecular biology Columbia; pp 47-48.

[12] Singh. S.P, Ghosh, M. (2005): A review on phytoremediation of heavy metals and utilization of it's by products.-Applied Ecology and Environmental Research 3(1):1-18.

[13] Zheljazkov, V.D., Nielson.,1996: Effect of heavy metals on peppermint and corn mint .Plant soil 178:59-66

[14] Bargagli R., Brown D.H., Nelli L., (1995): Metals bio monitoring with mosses, procedure for correcting soil contamination, Environmental Pollut, 89,169.

[15] Lacatusu, R., (2000).European soil bureau, No 4, Appraising levels of soil contamination and pollution with heavy metals, pp.93-402.

[16] Alloway, B.J. and Jackson, A.P. (1991): The behavior of heavy metals in sewage sludge amended soils. – Sci. Total Environ. 100: 151-176.

[17] Baker A. J. M. and Brooks R. R., (1989): Terrestrial Higher Plants which Hyperaccumulate Metalic Elements. A Review of their Distribution, Ecology and Phytochemistry. – Biorecovery 1; 81-126.

[18] Gleba D., Borisjuk, N. V., Borisjuk, L. G., Kneer, R., Poulev, A., Skarzhinskaya, M., Dushenkov, S. Logendra, S. Gleba, Y. Y., Raskin, I. (1999): Use of Plant Root for Phytoremediation and Molecular Farming. – Proc. Natl.Acad.Sci, USA. 96; 5973-5977