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Phytoremediation Potential of *Chromolaena Odorata* in Heavy Metal Polluted Environments

Nworu Jerome Sunday,[*a] Amuka Johnpaul Onyenezi,[a] Asionye Ezenwa Isdore[b] and Anyichie Ifeanyi Kenneth[a]

[a]*Department of Chemistry, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.*

[b]*Department of Marine Environment and Pollution Control, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.*

***Corresponding author E-mail address**: jeromenworu@nmu.edu.ng (Nworu Jerome Sunday)

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Abstract: Plants ability to mop up toxic metals, which is highly non-destructive remediation process encapsulated in phytoremediation has been studied. The use of weeds to take up toxic and heavy metals from contaminated soils and water environments are nature driven. *Chromolaena odorata* selected on the basis of its invasiveness and survival in extreme harsh conditions in almost all soils as well as its seemingly non-vegetative use in the Nigerian environment was evaluated using X-Ray Fluorescence Spectrophotometer (XRF) to investigate its heavy metal accumulating potentials. The results showed a high potency for heavy metal accumulation in the order; Fe >Pb>Mn>Ti> Cu > Zn > Ni > Cr > V > Co with lead (Pb) having the highest percentage up-take (100 %) and titanium (Ti) the least (39.8 %) compared with the control. Siam weed is therefore recommended for phytoremediation of heavy metal polluted environments and for the phyto-extraction of the metal in addition to its perceived medicinal properties. This study is aimed at expanding the glossary of potential plant sources for pollution control and environmental sustainability.

Keywords: Pollution control; Heavy metals; *Chromolaena odorata*; phytoremediation; Environmental sustainability.

1. Introduction

Heavy metals become an essential worry than other natural contaminations since heavy metals cannot be destroyed by debasement or degradation. The remediation procedure of debased and polluted soils, groundwater, and surface water by substantial metals needs a few strategies to expel the metals from debased zones.[1-3] A few strategies have been utilized for expelling the toxins from the polluted conditions. Soils that are polluted with substantial metals can be treated by phyto-mining, corrosive draining, soil washing, physical or on the other hand mechanical partition of the contaminant, electro-compound treatment, electrokinetics, synthetic treatment, warm or pyrometalurgical partition and biochemical procedures.[2-6] Other remediation procedures can be utilized for remediating substantial metals from sullied ground water such as extraction and treatment by actuated carbon adsorption, microorganisms use, air stripping, compound, natural, biochemical and biosorptive treatment advancements.[5,6]

Soil and water are frequently being contaminated by heavy metals directly or indirectly unlocked and exposed to the environment through various human activities on land and water. The exposure of the contaminants to humans through water is made more rampant due to poor waste management and grossly inadequate sanitation. Wastewater generated frequently in the environment equally contains heavy metals, several organic and inorganic pollutants, which independently or collectively interfere with the natural processes necessary for the survival of life and environmental stability thus threatening the integrity and the ecosystem balance.

Worldwide, almost 900 million people still do not have access to potable water and about half the population of developing countries of the World do not have access to adequate sanitation.[7] The WHO Report[8] revealed that about 80 % of ill health in the third world countries is water and sanitation related. Many, particularly neonates and children under five years die annually as a result of polluted water.[7,9] It has been reported that the prevalence of some of these disease cases especially diarrhoea is linked with high level of metal toxicity in the environment such as arsenic, cadmium, chromium, copper, lead, iron, mercury and zinc.[10] The high level of refuse dumps and carefree attitude of people to sanitation are serious problems continually affecting the soil, water quality and the health status of our people in the South-Eastern Nigeria.[11] This has been of major environmental concern considering that the source of this pollution is basically anthropogenic which can be minimized. Incessant disposal of industrial and urban waste, smelting, mining activities, leaching of rocks and ores, accidental and oil spillage, explosives, petroleum products, sewage sludge application to agricultural soils as well as the use of pesticides, herbicides and insecticides all contribute to the overload of heavy metals in the environment.[12] Other medium of exposure such as quarry activities and road construction can unlock unexposed metals in the environment as was in the case of lead pollution that affected Zamfara State people in Nigeria between 2010 and 2011.[11]

An impending danger with heavy metal pollution is the risk of non-biodegradability and biomagnifications in living cells,[13] hence the need for remediation strategies on soil.[14] Phytoremediation offers one of such strategies. It is a green technology based on the use of wild or higher plants to clean up contaminated soils. It takes advantage of the fact that a living plant can be considered a solar driven pump which can extract and concentrate a particular element from the environment making it a subject of intense public and scientific interest and a topic of many recent reviews.[15-17] Researchers have shown that the neglected none-food plant species have the potential to remove, degrade, metabolize or immobilize a wide range of contaminants including heavy metals.[16-19] However, lack of rapid growing high-biomass hyper-accumulating plants, elevated levels of metals/metalloids in soils and the presence of multiple contaminants often with low bioavailability hinders the application of phytoremediation techniques.[20] Besides, the consumption of plants as food by livestock and man alike could possibly lead to secondary metal pollution in living tissues. It is therefore imperative to concentrate on plants which are not necessarily food crop yet possessing the physiological and adaptive ability to remove heavy metals from soils and water.

Phytoremediation is the utilization of plants to expel contaminants from soil and water. It is a moderate yet ecologically inviting approach to evacuate poisons. Plant materials, for example, organisms, lichens, tree covering, tree rings and leaves of higher plants have been utilized for a long time to identify the statement, aggregation and circulation of substantial metals contaminations. Lower plants particularly greenery and lichens have been generally utilized because of their ability for metal collection. Some higher plants have likewise been utilized for biomonitoring of substantial metals.[1-3]

Chromolaena odorata (Siam weed) is an invasive, perennial weed native to the temperate region and has been introduced to numerous regions including Africa.[21] The adaptive response of the plant to contaminated and non-contaminated soils as well as its non-food properties justifies its use in phytoremediation. These characteristics together with its physiological and morphological abilities to survive all weather and hyper-accumulate pollutants through its roots and translocate same to its leaves without any toxicity syndrome are a plus to its application in phytoremediation. It grows freely and in abundance enriching the soil perhaps with nitrogenous nutrients. It survives bush burning and it is also believed to be allelopathic. Paucity of knowledge of its applications renders it a waste in Nigeria and parts of Africa. Though it has been observed to have pharmacological and medicinal properties,[22-24] its use to clean up heavy metal contaminated soils and wastewater will further boost its applications and prominence.

In view of the adaptability, invasive and non-edible nature of *Chromolaena odorata* to both humans and livestock alike, its use in phytoremediation is highly recommended. The target of this research was to evaluate the potency of *C. odorata* leaf in accumulating a wide range of heavy metals from soil.

2. Experimental Section

2.1. Study Site and Sample Collection

The study area is Enyigba Lead-Zinc mines in Abakaliki Local Government Area of Ebonyi State, which happens to be one of the lead endemic Areas in the South-Eastern Nigeria. The Enyigba Mine is situated at the outskirt of the state capital, Abakaliki Metropolis and majority of the inhabitants of this area thrives on farm work and feeds on crops and water from the same soil.

Control leaf samples of *Chromolaena odorata* were taken from the College of Health Sciences, Ebonyi State University, and a relatively unpolluted area located within the Abakaliki Metropolis. The test leaf samples were obtained in open field from the Mine sites at sampling point distances ranging from 200 – 400 meters away from the Mine's Administrative Block. The test samples were coded 1 – 3 (designated as composite sample), while the control sample was labeled 4.

2.2. Sample Preparation

The leaf samples were washed in running water to eliminate dust, dirt and other possible adhering parasites and then washed with distilled water without squeezing. The clean leaf samples were air-dried and further dried in an electric oven maintained at 65°C for 72 – 96 hours depending on the quantity. The dried samples were ground into powder using a ceramic coated laboratory mortar. Procedure for XRF analysis for metal determination was followed in accordance with Standard Operating Method[25] at the Centre for Energy Research and Development, Obafemi Awolowo University, Ile-Ife, Osun State.

2.3. Chemical Analysis

A 1.0 g of the pulverized leave sample was weighed, pelletized then introduced into the X-ray Fluorescence Analyzer where it was irradiated for 20 minutes with 25 KV voltages and 50 µA energy. The resulting X-Ray Fluorescence Spectrum characteristic of each metal ion was interpreted into their corresponding concentrations registered on the digital read out device.

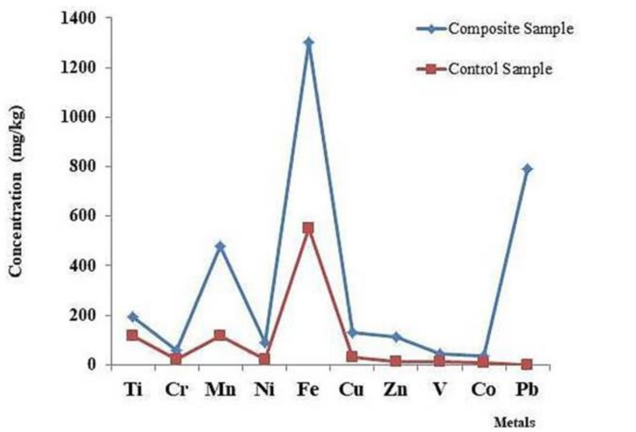

Fig. 1. Variations in Heavy metal accumulation in the Leaves of *C. odorata*

Table 1. Mean Concentration of Total metal ion in *C. odorata* leave samples (mg/kg)

	Metals									
	Ti	Cr	Mn	Ni	Fe	Cu	Zn	V	Co	Pb
Mean ± SE of Composite Sample	193.50± 8.47	55.±3.27	477.3 ±7.89	91.17 ±2.31	1302.7±1 0.58	130.00±2.50	113.3± 2.12	43.17 ±3.46	33.50 ±1.35	789.67 ±16.93
Mean ± SE of Control Sample	116.50± 6.93	23.50±2.9	117.5 ±6.35	21.50±2.31	552.50± 6.93	32.00± 2.31	12.00± 0.00	12.00± 3.46	8.50± 1.73	0.00± 0.00
Percentage (%) Metal Uptake	39.80	57.90	75.40	76.40	57.60	75.00	89.40	72.20	74.60	100.00
WHO/FAO	-	-	-	-	48.00	30.00	60.00	-	-	2.00

2.4. Statistical Analysis

Triplicate determinations were carried out on each sample and data generated were reported as mean ± standard error. One-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) and Fisher's Least Square Difference (LSD) at 95% confidence limit were used to determine the significant difference within and between groups.

3. Results and Discussions

The XRF analysis of metal uptake of *C. odorata* leaves is presented in Table 1. The mean value of each metal ion was compared with that of the control sample mean and the WHO/FAO standards for plants.

The composite samples consist of *C. odorata* leaves collected from three different locations within the Enyigba Pb-Zn Mine area while the control sample refers to *C. odorata* leaves collected from a relatively unpolluted area (College of Health Sciences campus of Ebonyi State University) which is located about 14 Km away from the Enyigba Mine area.[26] The result presented in Table 1 and Fig. 1 showed the mean values of metal ions accumulated in the leaves of the weed of the composite and the control samples. The percentage metal uptake represents the excess metal ion accumulation in the composite sample when compared to the control sample. From Table 1, the trend of metal ion uptake showed Fe >Pb>Mn>Ti> Cu > Zn > Ni > Cr > V > Co with a maximum uptake of Pb (100 %) compared with the control due to absence of Pb in the control sample leaves. The composite leave samples had over 50 % metal ion accumulation when compared to the control sample with the exception of Ti which had approximately 40 % accumulation.

Comparing the results with established guideline values of the WHO/FAO for edible plants, the amount of each metal accumulated by the plant were excessively above the tolerable limits recommended by WHO/FAO. It is interesting to reiterate that *C. odorata* is an invasive plant which is neither edible to humans nor livestock. Therefore, since it has a good potential to accumulate a wide range of heavy metals, it fits well as a phytoremediation weed. The risk of secondary contamination within the food chain is also eliminated because it is not edible. The mean value of hyper-accumulation of Pb (789.67 ± 16.93 mg/kg) obtained in this study was far above the 103.73 ± 10.20 mg/Kg reported in a simulation study by Aiyesanmi[27] and Yan et al.[28] The variations may be due to levels of the metal in an area or the contact period of the plant with the metals as well as the bioavailability of the metal in the soil matrix.

The ANOVA and Fisher's Least Square Difference (LSD) results show that the concentration of heavy metals in the leaf samples of *C. odorata* in the unpolluted area (control sample) was significantly high compared with the WHO/FAO guideline limits but much lower than those obtained in the Enyigba Pb-Zn Mine areas. This entails that the bioaccumulation of metals in the leaves is not dependent solely on the availability of the metals in the contaminated soil but more on the capacity of the plant to translocate the metals from their roots through the shoot system to the leaves, a phytoremediation technique known as phytoextraction.

4. Conclusions

The plant species used in this experiment though are generally considered an invasive weed, accumulated a wide range and very high amounts of heavy metals namely; Ti, Cr, Mn, Ni, Fe, Cu, Zn, V, Co and Pb. The concentration of these metals in the leaves of *C. odorata* indicates the potency of the plant to be utilized as a multi-metal extractor through phytoextraction process. The high concentrations of accumulated metals from the control samples equally show that the plant can be used to treat any sick soil or wastewater environment.

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Conflicts of Interest

The authors declare no conflict of interest

References

1 Sumiahadi A.; Acar R. A Review of Phytoremediation Technology: Heavy Metals Uptake by Plants. *IOP Conf. Series: Earth and Environmental Science*, 2018, **142**, 012023. [CrossRef]

2 Abhilash M.R.; Srikantaswamy S.; Shiva Kumar D.; Jagadish K.; Shruthi L. Phytoremediation of Heavy Metal Industrial contaminated soil by *Spiracia oleracea L* and *Zeamays L. Appl. Sci.,* 2016, **4**, 1. [CrossRef]

3 Sadowsky M.J. In Phytoremediation: Past Promises and Future Practices- Proceedings of the 8th International Symposium on Microbial Ecology, Halifax, 1999, **19**, 72 -85. [CrossRef]

4 Kaplan M.; Orman S.; Kadar I., Koncz J. Heavy Metal Accumulation in Calcareous Soil and Sorghum Plants after Addition of Sulphur-Containing Waste as a Soil Amendment in Turkey. *Agric. Ecosyst. Environ*., 2005, **111**, 41-46. [CrossRef]
5 Abii T A.; Nwosu P C. The Effect of Oil Spillage on the Soil of Eleme in Rivers State of the Niger Delta Area of Nigeria. *Res. J. Environ. Sci*., 2019, **3**, 316–320. [CrossRef]
6 Essien O.E.; John I.A. Impact of Crude-Oil Spillage Pollution and Chemical Remediation on Agricultural Soil Properties and Crop Growth. *J. Appl. Sci. Environ. Manage*., 2010, **14**, 147–154. [CrossRef]
7 UNEP. Sick Water? The Central Role of Wastewater Management in Sustainable Development, UNEP and UN-Habitat. 2010, 183. [Link]
8 WHO. Guidelines for Drinking Water, Quality and Evaluation Vol. 3, Surveillance and Control of Community Supplies, WHO Geneva, 1997. [Link]
9 Corcoran E.; Nellemann C.; Baker E.; Bos R.; Osborn D.; Savelli H. Sick Water? The Central Role of Wastewater Management in Sustainable Development, a Rapid Response Assessment. United Nations Environmental Programme, UN-Habitat, Grid-Arendal. 2010, **8**, 978-982. [Link]
10 Wilberforce O.J.; Nwabue F.I.; Afiukwa J.N. Analysis of Heavy Metals in Soils of Enyigba and Abakaliki Using Proton Induced X-Ray Emission (Pixe) Spectroscopy. *Environ. Pollut*., 2012, **1**, 183-193. [Link]
11 Izah S.C.; Chakrabarty N.; Srivastav A.L. A Review on Heavy Metal Concentration in Potable Water Sources in Nigeria: Human Health Effects and Mitigating Measures. *Expo. Health*, 2016, **8**, 285-304. [CrossRef]
12 D'Amore J.J.; Al-Abed S.R.; Scheckel K.G.; Ryan A.J. Methods for Speciation of Metals in Soils: A Review. *J. Environ. Qual*., 2005, **34**, 1707-1745. [CrossRef]
13 Adeyeye E.I. Trace Metals in Soils and Plants from Fadama Farms in Ekiti State, Nigeria. *B. Chem. Soc. Ethiopia*, 2005, **19**, 23–34. [CrossRef]
14 Kirpichtchikova T.A.; Manceau A.; Spadini L.; Pargili F.; Marcus M.A.; Jacguet T. Speciation and Solubility of Heavy Metals in Contaminated Soil Using X-Ray Micro Fluorescence, EXAFS, Spectroscopy, Chemical Extraction and Thermodynamic Modeling. *Geochim. Cosmochim. Acta*, 2006, **70**, 2163-2190. [CrossRef]
15 Salt D.E.; Blaylock M.; Kumar P.B.; Dushenkov V.; Ensley B.D.; Chet I.; Raskin I. Phytoremediation: A Novel strategy for the Removal of Toxic Metals from the Environment Using Plants. *Nat. Biotechnol*., 1995, **13**, 468-468. [CrossRef]
16 Raskin I.; Smith R.D.; Salt D.E. Phytoremediation of Metals: Using Plants to Remove Pollutants from the Environment. *Curr. Opin. Biotechnol*., 1997, **8**, 221-226. [CrossRef]
17 Cunningham S.D.; Ow D.W. Promises and Prospects of Phytoremediation. *Plant Physiol.*, 1996, **110**, 715-719. [CrossRef]
18 Salt D.E.; Smith R.D.; Raskin I. Phytoremediation. *Annu. Rev. Plant Physiol. Plant Mol. Biol*., 1998, **49**, 643-668. [CrossRef]
19 Pilon-Smits E. Phytoremediation. *Annu. Rev. Plant Biol.*, 2005, **56**, 15-39. [CrossRef]
20 McGrath S.P.; Zhao F.J.; Phytoextraction of Metals and Metalloids from Contaminated Soils. *Curr. Opin. Biotechnol*., 2003, **14**, 277-282. [CrossRef]
21 Prasad V.; Caroline A.E.; Habib A.; Ashok S. Dinosaur Coprolites and the Early Evolution of Grasses and Grazers. *J. Original Scientific Res*., 2005, **310**, 1177-1180. [CrossRef]
22 Anup K.C.; Harikrishna R.; Shailaja B. Evaluation of Antioxicant Activity of the Leaves of Eupatoriumodoratum Linn. *Int. J. Pharm. Technol*., 2010, **4**, 77-79. [CrossRef]
23 Chen Man N.B. Phytochemical Analysis of the Leaves of *Chromolaena odorata* (Asteraceae). B.Sc. Hons. Thesis, Faculty of Applied Sciences-University of Technology, Mara, 2010, 9-12. [CrossRef]
24 Anyasi R.O. Growth of *Chromolaena Odorata* (Siam weed) in Two Soil Samples Studied under Greenhouse Condition. *Int. J. Med. Arom. Plants*, 2012, **2**, 310-322. [CrossRef]
25 Figi R.; Nagel O.; Tuchschmid M.; Lienemann P.; Gfeller U.; Bukowiecki N. Quantitative Analysis of Heavy Metals in Automotive Brake Linings: a Comparison between Wet-Chemistry based Analysis and In-Situ Screening with a Handheld X-Ray Fluorescence Spectrometer. *Anal. Chim. Acta*, 2010, **676**, 46-52. [CrossRef]
26 Nnabo P.N.; Orazulike D.M.; Offor O.C. The Preliminary Assessment of the Level of Heavy Elements Contaminations in Stream Bed Sediments of Enyigba and Environs, South Eastern Nigeria. *J. Basic Phys. Res*., 2011, **2**, 43-52. [CrossRef]
27 Aiyesanmi A.F.; Okoronkwo A.E. Sunday O.M. Lead Accumulation in Siam Weed (*Chromolaena odorata*), Node Weed (Synedrella nodiflora) and Water leave (Talinum triangulare): Potential phytoremediators. *Arch. Appl. Sci. Res*., 2012, **4**, 360-371. [CrossRef]
28 Yan A.; Wang Y.; Tan S.N.; Yusof M.L.M.; Ghosh S.; Chen Z. Phytoremediation: A Promising Approach for Revegetation of Heavy Metal-Polluted Land. *Front. Plant Sci*., 2020, **11**, 359. [CrossRef]