AASCIT Communications
Volume 3, Issue 5
ISSN: 2375-3803

American Association for Science and Technology

Phytoremediation of Cobalt, Lead and Zinc Using Selected African Plants

Anarado C. Ebere Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka., Nigeria

Anarado C. John Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka., Nigeria

Egwuatu C. Ijeamaka* Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka., Nigeria

Umedum N. Lilian Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka., Nigeria

Okoye P. A. Chuma Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka., Nigeria

Received: June 27, 2016; **Accepted**: August 3, 2016; **Published**: August 27, 2016

Keywords

Phytoremediation, Cobalt, Lead, Zinc, *Telfaira occidentalis*, *Bryophyllum pinnatum*, *Talinum triiangulare*, *Abelmoschus esculentus* and *Vigna unguiculata*

The phytoremediating capacities of *Telfaira occidentalis, Bryophyllum pinnatum, Talinum triiangulare, Vigna unguiculata,* for metal ions, were studied. Soil samples, tested for Cobalt, lead and Zinc ions concentration levels were inoculatedwith 0.1M solution of $Co(NO_3)_2$, $Pb(NO_3)_2$ and $Zn(NO_3)_2$ before planting the above species. The roots, stems and leaves of the plants were harvested at two weeks interval, dried, ashed and digested with concentrated HNO_3. The metal ions absorbed by the various plant parts were analysed using Atomic Absorption Spectrophotometer Buck 200A. The results indicated that *Vigna unguiculata*absorbed Pb^{2+} and Zn^{2+} most. *Talinum triangulare*showed greater absorbance for Co^{2+}, *Bryophyllum pinnatum*absorbed Pb^{2+} better than others except *vignaunguiculata*. Further, *Telfairia occidentalis*absorbed Zn^{2+} and Co^{2+} better than *Bryophyllum pinnatum* and *Albelmoschus esculentus*. Co^{2+} was toxic to *Vigna unguiculata* and *Albelmoschus esculentus.* In general, the African plants could be used to sequestrate metals from polluted soils.

Introduction

The decontamination of soils and water contaminated with various anthropogenic chemicals is a global problem that has consumed considerable economic resources [1]. Over the past two decades, pollution prevention and the clean-up of contaminated soils and water have become a world wide environmental priority [1, 2]. The discovery of metal hyper accumulating properties in certain plants has suggested that it may be feasible to use plants for clean-up of heavy metal contaminants in soil and water [2]. The use of green plants or vegetation, to sequester, degrade, contain and remove inorganic and organic contaminants in soils, sediments, surface waters and ground waters is known as phytoremediation[1-10].

Phytoremediation and bioremediation are often used interchangeably. Bioremediation employs microbe-based technology for degradation of organic compounds such as polycyclic aromatic hydrocarbons (PAH_s). Such approaches have no effect on most of heavy metals. Phytoremediation involves the planting of trees, or grasses which can be grown and harvested economically leaving only residual levels of pollutants. By nature, it is a relatively inexpensive technology when compared with technologies that involve the use of large scale energy consuming equipment [11].

It has been found that soils with pH of 5-6 contain relatively more of the metal ions [12]. Further, the limitation for a successful phytoremediation lies in the availability of the metals in the soils. For example, lead ions an important environmental pollutant is highly immobile in soils [12]. These situations notwithstanding, phytoremediation has been found to be relatively cheap and effective in removal of metal contaminants from the environment.

The remediating capacities of some plants have been reported [13, 14]. Soils contaminated with zinc and copper have been successfully phytoremediated using three species of *brassica* plant. However, the study showed that the presence of 6.5mgL^{-1} zinc and 0.32mgL^{-1} copper inhibited growth of the various species. The uptake of Fe and Mn by these species of plants were equally reduced at the same concentration levels. That rag weed and *thlaspi rotundifoluim*are better lead removers from polluted environments than alpinc pennycress of the species of plants tested in St Paul Minnesota [2, 15]. Pennycress was found to be the best in removal of cadmium, zinc and lead [15]. Zinc toxicity was however experienced at 500ppm. Cobalt is not often freely available in the environment but when not bound to soil or sediment, its uptake by plants or animals is relatively high [16]. When plants grow on contaminated soils, they will accumulate very small particles of cobalt, especially in the parts of the plants we eat such as fruits and seeds [14].

Little or nothing is known about the use of some African plants for phytoremediation. This study therefore introduces five plants popularly known in Nigeria and Africa in general for remediation of soils contaminated with cobalt, lead and zinc.

Experimental

Materials and Methods:

The seeds of *vigna unguiculata, abelmoschus esculentus, telfairia occidentalis*and *talinum triangulare* were bought from Awka market in Anambra State, Nigeria. Also the seedlings of *bryophyllum pinnatum* were uprooted from a nearby bush in the same city, and the roots washed free of soil on which they originally grew. The soil samples collected from a nearby farm were placed in plastic containers and inoculated with 20cm^3 of0.1M each of $Co(NO_3)_2$, $Pb(NO_3)_2$, $Zn(NO_3)_2$. The seeds and seedlings were planted in the inoculated soils. They were also planted in the uninoculated soil samples as controls. The containers were watered daily. The plants were left to grow until after 4 weeks. Harvesting was done every fortnight during which the leaves, stems and roots were separated and air dried.

Finally the dried plant parts after ashing at 300°C were digested separately for 2½ hours using HNO_3. Both digested plants, inoculated soil after harvest and uninoculated parent soil were assayed for cobalt, lead and zinc concentrations using Atomic Absorption Spectrophotometer Buck 200A.

Results and Discussion

Observation showed that the seeds germinated between 10-14 days. The results of the investigation into the phytoremediation capabilities of *Telfairiaoccidentalis, Abelmoschusesculentus, Vignaunguiculata, and Talinumtriangulara*and *bryophyllumpinnatum*are shown in Table 1.

Table 1. *Result of the phytoremediation process.*

Plant	Time	ROOT			LEAVES			STEM		
		Pb	Zn	Co	Pb	Zn	Co	Pb	Zn	Co
Telfairiaoccidentalis	4 wks	0.0464	0.2362	0.0436	0.025	0.2037	0.014	0.0275	0.0229	0.0222
	6 wks	0.1806	0.3226	0.1291	0.0143	0.1399	0.0077	0.0277	0.1087	0.0698
	8 wks	0.594	0.3973	0.3097	0.1193	0.063	0.0035	0.029	0.3973	0.0797
	10 wks	0.27	0.5266	0.6433	ND	0.063	ND	0.051	0.2398	0.2574
Bryophyllumpinnatum	4 wks	0.0088	0.041	0.001	0.1184	0.0337	0.0092	0.0061	0.041	0.0489
	6 wks	0.0091	0.0672	0.0647	0.0967	0.209	0.4714	0.0091	0.212	0.055
	8 wks	1.825	0.0902	0.0825	0.4083	ND	ND	0.0293	0.2418	0.002
	10 wks	D	D	D	D	D	D	0.136	D	D
Talinumtriangulare	4 wks	0.1463	ND	0.02	0.0091	0.26	ND	0.008	0.0176	0.128
	6 wks	0.02	ND	1.9	0.0052	0.2742	ND	0.3675	0.101	0.0961
	8 wks	ND	ND	ND	0.2042	0.4467	ND	0.6231	0.1904	0.1345
	10 wks	ND	ND	ND	ND	ND	ND	0.18	0.3547	ND
Abelmoschusesculentus	4 wks	0.0093	ND	NG	0.0109	0.26	NG	0.1709	0.339	NG
	6 wks	0.0737	ND	NG	0.1885	1	NG	0.2704	0.35	NG
	8 wks	0.15	ND	NG	0.725	ND	NG	ND	ND	NG

Plant	Time	ROOT			LEAVES			STEM		
		Pb	Zn	Co	Pb	Zn	Co	Pb	Zn	Co
Vignaunguiculata	10 wks	ND	ND	NG	ND	ND	NG	ND	ND	NG
	4 wks	4.4	0.375	NG	0.1273	0.424	NG	0.6444	0.0695	NG
	6 wks	0.3625	0.4115	NG	0.137	0.5579	NG	0.0685	0.1305	NG
	8 wks	0.0817	0.087	NG	1.1	0.4029	NG	0.4143	0.5929	NG
	10 wks	ND	ND	NG	1.9044	ND	NG	ND	0.0513	NG

KEY: D = Dead, ND = No growth, NG = No growth

Results from the Table show that the roots absorbed Pb at an optimum period of 8 weeks; Zn and Co at an optimum period of 10 weeks. The difference in absorptivity of the metals may be related to atomic size and migration potential of the ions. Co is absorbed by the roots in greater quantity within 10 weeks while Pb is absorbed least in 10 weeks. Also it is observed that in 10 weeks, there is sharp reduction in absorption of Pb in the roots of the plants, this could be as a result of the process of phytovolatilization taking place [1]. There is continuous absorption of the metal ions by the roots at different time of harvest. This implies that the plant can be used for phytoremediation.

The result of investigation into the amount of metal absorbed by the stem samples of *telfairia occidentalis* shows that there is continuous increase in absorption of all the metal ions as time of harvest increases. At 10 weeks of harvesting, the quantity of Pb ions absorbed is smaller than the quantity of Co or Zn absorbed. Pb is also toxic to plants and so metal intake may be smaller.

In the leaves of the plants, there is continuous increase in absorption of Pb as time of harvest increases, but there is decrease in absorption of Zn and Co as time of harvest increases. The storage facilities of the plant for these metals may be probably on the roots and stems. The quantity of Pb on the leaves may have been contributed to by air-lead deposit. Some plants have the ability to accommodate lead dust on the surface of their leaves.

Generally the roots of *telfairia occidentalis* absorbed most metal ions (Pb, Co & Zn), while the leaves absorbed least. This could be as a result of the precipitation or immobilization of metal contaminants in the soil surfaces or within the root tissues (phytosequestration) [2].

The result of the investigation into the amount of metal absorbed by the roots of *bryophyllum pinnatum* at different time of harvest is shown in the Table. The results show that there is increase in absorption of Pb, Co and Zn as time of harvest increases. However the plants died easily before the 10th week (the dead stem of the plant inoculated with Pb was found and analysed), hence no result for all others. Also the total uptake of Pb is the greatest while Co is the least. This could be as a result of the soil not being acidic. It has been found that Co mobilizes easily in very acidic conditions [12, 13, 16].

The results also show that Zn is absorbed mostin the stem and Co the least. This could also be as a result of the soil not being too acidic [16]. The result of the analysis indicates that in the leaves Co and Zn are absorbed at optimum time of 6 weeks while Pb is absorbed at optimum time of 8 weeks. The leaves of the plants withered as time of harvest approached 9 weeks.

Even though this plant can be regarded as a wild medicinal plant, it is surprising that it is greatly affected by pollutants absorbed. This could be as a result of presence of saponins, flavonoids, and tannins in the plant. However, results show that it can be used to phytoremediate soil contaminated with Pb, since its total uptake is up to 3.8mgL^{-1}.

From result shown in the Table, in the roots of *talinum triangulare,* there is increase in the absorption of Co as the time of harvest increases, there is decrease in absorption of Pb as the time of harvest increases. Zn is not detected in the root of *talinum triangulare*. Also Pb is absorbed at optimum time of 8 weeks in the stem while there is sharp decrease at the 10th week.

In the stem there is increase in the absorption of Zn as time of harvest increases. The reverse observation is seen with Co. This continues to emphasis the different capabilities which plants have for sequestration of metal ions from solution [2]. Zn is highly absorbed by the leaves of *talinum triangulare* while Co is not absorbed at all.

Generally, the absorptivity of parts of *talinum triangulare* may be expressed as stems>roots>leaves.

Also result shows that the roots of *abelmoschus esculentus* absorbed only Pb ions, while Zn and Co were not detected. Further, the stem absorbed the Pb and Zn only within 6 weeks of harvest. The plant did not show absorption at the 10th week. The amount of Pb on the leaves of the plant may also be as a result of air-borne Pb or Zn. Co was not absorbed by the plant parts and this could be as a result of Co being toxic to the plant. The plants died at inoculation stage.

The results indicate that *abelmoschus esculentus* could be used to phytoremediatePb and Zn. The amount of Pb absorbed by the plant especially the leaves indicates that the consumption of the leaves of this plant may be unsafe.

Generally, the total plant uptake may be expressed in the order Zn>Pb>Co. Comparing the uptake by parts of the plant, an order leaves>stems>roots may be established.

Table1 indicated the result of metal uptake of the root of *vigna unguiculata*. It is observed that Pb is more absorbed than Zn while Co is toxic to the plant as plants died at inoculation stage. The optimum absorption of Zn is after 6 weeks in the roots and leaves, 8 weeks in the stem while the optimum absorption of Pb is after 4 weeks in the roots and stems, and 10^{th} week in the leaves.

The decrease in the absorption of Pb in the roots as the time of harvest increases could be as a result of phytoextraction (phytomining) of Pb, which is the accumulation of contaminants in the shoots and leaves of plants[3]. In the stem, the optimum absorption for Pb is 4 weeks while that of Zn is 8 weeks, when the stem was harvested after 10 weeks of planting, the value of Zn decreased. This is probably as a result of phytovolatilization [2].

In the leaves, there is a progressive increase in the uptake of Pb by the plant. This can be explained in terms of phytomining process in the absorption of metal ions by plants [3].

The non growth of plant inoculated with Co is an indication that the plant cannot be used to phytoremediate a soil polluted by Co.

From the result, it is clear that *telfairia occidentals* absorbs Zn more than Co and Pb the least. Also *bryophyllum pinnatum* absorbs Pb more than Zn and Co the least. Further, *talinum triangulare* absorbs Co more than Zn and Pb the least. *Abelmoschus esculentus* absorbs Zn more than Pb and Co is toxic to the plant. *Vigna unguiculata* absorbs Pb more than Zn and Co is toxic to the plant.

Conclusion

Vigna unguiculata absorbs Pb most, and *Telfairia occidentalis* the least. Also *Vigna unguiculata* absorbs Zn most and *Bryophyllum pinnatum* the least. *Talinum triangulare* absorbs Co most and none in *Vigna unguiculata* and *Abelmoschus esculentus*. In general, these African plants could be used to sequestrate metals from polluted soils. ■

Anarado C. Ebere

Anarado C. Ebere received her Bachelor and Master of Science Degrees in Pure and Industrial Chemistry from Nnamdi Azikiwe University, Awka, with specialty in Organic Chemistry (Phytochemistry). She is a lecturer in the same university, where she is pursuing her doctorate degree programme. She is a member of the Chemical Society of Nigeria with well researched articles in reputable journals.

Anarado C. John

Anarado C. John holds a Ph.D. in Analytical and inorganic Chemistry Chemistry and is a lecturer in the Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University Awka. He is a member of the Chemical Society of Nigeria with well researched articles in reputable journals

Egwuatu C. Ijeamaka

Egwuatu C. Ijeamaka holds a Ph.D. in Physical Chemistry and is a senior lecturer in the Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University Awka.
Email address: chy4jesusalwayz@yahoo.com

Umedum N. Lilian

Umedum N. Lilian received her Bachelor and Master of Science Degrees in Pure and Industrial Chemistry from Nnamdi Azikiwe University, Awka, with specialty in Organic Chemistry (Phytochemistry). She is a member of the Chemical Society of Nigeria with well researched articles in reputable journals. She is also doing her Doctorate degree programme

Okoye P. A. Chuma

Okoye P. A. Chuma is a professor Of Analytical and Environmental Chemistry. He was one time Head of the Department of Pure and Industrial Chemistry and Dean Faculty of Physical Sciences, Nnamdi Azikiwe University, Awka. He is widely published in international journals. He is a Fellow of the Chemical Society of Nigeria.

References

[1] Scheper T. (2002), Advances in Biochemical Engineering/Biotechnology (phytorem edition), Springer verlag, New York, vol 78, pp 1-103.

[2] Ilya R. and Burt D. E. (2000), Phytoremediation of Toxic metals (using plants to clean up the environment), John Wiley & sons, Inc. New York, pp 1-89.

[3] Nancy A., Dawn C., Kelly M., Steve R.and Bruce P.(2000): Introduction to phytoremediation, International Journal of phytoremediation, 6: 3-6.

[4] Hassani A. H., Nouri J. Mehregan I., Moattar F., Sadeghi Benis M. R. (2015), Phytoremediation of Soils Contaminated with Heavy Metals Resulting from Acidic Sludge of Eshtehard Industrial Town using Native Pasture Plants, Journal of Environment and Earth Science(IISTE) 5(2): 87-93.

[5] Otaru A. J., Ameh C. U., Okafor J. O., Odigure J. O., Abdulkareem A. S., Ibrahim S. (2013), Study on the Effectiveness of Phytoremediation in the Removal of Heavy Metals from Soil Using Corn, International Journal of Computational Engineering Research,3(4): 87-93.

[6] Rajendra P. B., Abhilasha S., Nandkishor S., Asha T., Shivbhanu M., Jagjeevan R. C. (2014), Phytoremediation of Heavy Metal Toxicity and Role of soil in Rhizobacteria, International Journal of Scientific and Research Publications, 4(1): 1-5.

[7] Stephen J. C., Khaled S., and Eshmaiel G. (2013), Phytoremediation of heavy metal contaminated soil using different plant species, African Journal of Biotechnology, 12 (43): 6185-6192.

[8] Amin M., Hamidi A., Mohammad A. Z., Shuokr Q. A. Razip M., Selamat B. (2013), Phytoremediation of Heavy Metals from Urban Waste Leachate by Southern Cattail (Typhadomingensis), International Journal of Scientific Research in Environmental Sciences (IJSRES), 1(4): 63-70.

[9] Ahemad, M. Remediation of metalliferous soils through the heavy metal resistant plant growth promoting bacteria: Paradigms and prospects. Arab. J. Chem. 2014, doi:10.1016/ j.arabjc.2014.11.020.

[10] Ali, H.; Khan, E.; Sajad, M. A. (2013), Phytoremediation of heavy metals-Concepts and applications. Chemosphere, 91: 869–881.

[11] USEPA (2000): Applied natural Science, cost estimates of a poplar tree phytoremediation system (monitoring and upkeep, economics) Section 6-8.

[12] Phytoremediation (2000): Description, Limitations and concern applicability, http://www.cpeo.org/techtree

[13] In sitn Biological Treatment http://www.tritrigov/matric2/section4/4-3html

[14] Fiegl L. J., Bryan P. M., Jill A. K., May E.F. & Kinberly G. (2000): Phytoremediation of vad section 4.

[15] Ebbs S.D. and Kochian L. V., (1997) Toxicity of Zinc and Copper to Brassica Species: Implications for Phytoremediation, Journal of Environmental Quality 26(3): 776-781.

[16] Mc Graw-Hill Encyclopedia of Science & Technology (1997): Toxicity of Cobalt, Mc Graw-Hill publishers, vol 4, pp 100-107.