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Phytoremediation of Heavy Metals (Cu, Zn, and PB) Contaminated Water Using Water Hyacinth (Eichornia Crassipes)

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Abstract: *Water samples contaminated with heavy metals (Zn, Cu and Pb) were subjected to phytoremediation method using water hyacinth (E. crassipes) for the period of 8 weeks. The study involved the preparation of the heavy metals solutions in different concentrations (their pH values supplemented) into eight 40L plastic containers, with six containers having the solutions of heavy metals (Zn, Cu and Pb in their replicates) while two plastic containers served as the control. Thereafter, the experiment was monitored and analyzed for 8 weeks for metal accumulation by the plant. Water analysis was carried out to know the concentration of heavy metals present in the water during these periods and the plants were also analyzed using Atomic Absorption Spectrophotometer. The results obtained were further interpreted using SPSS (T-test) to determine the mean concentration obtained from week 1 to week 8.The results obtained for Zn were 0.28 ,0.23 ,0.13 ,0.04 ,BDL,0.02 ,BDL,BDL .Also the results obtained for Cu from week 1 to week 8 were 0.04 ,0.07 ,0.03, BDL ,BDL ,BDL ,BDL ,BDL. More so, the results obtained for Pb from week 1 to week 8 were 0.13, 0.45, 0.05, BDL, BDL, BDL, BDL, BDL. At the end of the 8 weeks of remediation, it was observed that the concentrations of the metals in the water were below the detection limit but accumulated in the plant. Also, the results of the Bioconcentration factor (BCF) showed that the investigated plant (E.crassipes) hyperaccummulated Zn than other heavy metals. Therefore, heavy metal uptake by E. crassipes using phytoremediation technology seems to be a prosperous way to remediate heavy metal contaminated environment.*

Keywords: *Contamination, E. crassipes, heavy metals, phytoremediation, water hyacinth.*

I. Introduction

In natural aquatic ecosystem metals occur in low concentrations normally at the nanogram to microgram per liter level. In recent time, however the occurrence of metals in excess of natural loads have become a problem of increasing concern. This situation thus arises as a result of the rapid growth in population, increased urbanization, expansion of industrial activities, exploration and exploitation of natural resources, extension of irrigation and other modern environmental regulation [(1)].

Water sediments and biota are generally metal reservoir in aquatic environments [(2)]. The concentrations of heavy metals in water may vary considerably depending an annual and seasonal fluctuation [(3)]. Bower [(4)] noted that the extent of accumulation in biota is dependent on the chemical effect of the metal its tendency to bind to particular materials and on the lipid content and composition of the biological tissue. At low levels, some heavy metals such as copper, zinc and iron are essential for enzymatic activities and many biological processes while other metals such as cadmium, mercury and lead have no known essential role in living organisms and are toxic at even low concentrations. The essential metal also become toxic at high concentrations .Therefore, the need arises to constantly monitor heavy metals and find a way of removing them from the ecosystem before the threshold level is reached. Apparently, not every plant can be used for phytoremediation. A plant that is able to take up more metals than normal plant is called an hyperaccumulator and this hyperaccumulator can absorb more heavy (toxic) metals that is present in water [(5)].

Traditional technologies for the removal of pollutants can be successful in specific situation but they are not cost effective. There are very dynamic efforts to develop new more cost – effective and eco-friendly and now, phytoremediation which is bound on the use of plant to extract, sequester or detoxify pollutants is on the front line [(6)].

The word "phyto" means plants. This process involves utilizing plant such as (E. Crassipes) in remediating environmental contaminants. It generally refers to the use of plants without additional excavation. Different actions occur to absorb a degrade contaminates across a variety of scales. The plant's root zones must be in contact with the contaminated water where the contaminants are being removed [(7)]. The root membrane acts as a filter in a process termed, rhizofilteration, and eventually absorb the pollutant [(8)]. Phytoremediation is

employed to describe the uptake mechanism of both organic and inorganic contaminants. For organic contaminants, it involves phytostabilization, rhizodegradation, rhizofilteration, phytodegradation and phytovolatilization. These mechanisms are related to organic contaminant property are not able to be absorbed into plant tissue and for inorganic, mechanism which can be involved are phytostabilization, rhizofiltration, phytoaccumulation and phytovolatilization[9]. Phytodegradation occurs when metabolic processes with the plant breakdown the organic chemical while phytoaccumulation occurs when typically inorganic compounds are absorbed into the plants system [10].

The aquatic macrophyte called water hyacinth (Eichhornia crassipes) is not new in the ecological history of man [11]. Infact, it has been popularly described as the most troublesome weed of the world because of its rate of multiplication. Its rapid growth has clogged major waterways and created problems associated with navigation, natural security, irrigation and drainage, water supply, hydro electricity and fishing in many countries [11]. The water hyacinth found in Nigerian waters is of the South American species. It is believed to have found its way into the Nigerian waters from neighbouring Republic of Benin [12]. Since it entered waters, effort to eradicate it have not been successful, hence the need to put it into productive use is very important. One of such use is in the clean up of polluted sites; phytoremediation [3].

Among the different remediation techniques, phytoremediation has been proven to have the most effective approach to alleviate the environmental problems associated with contamination. It is eco –friendly, cost effective, not harmful, not expensive and it allows the treatment of the impacted water without any interruption. Therefore, it is imperative to know the level at which water hyacinth (Eichornia crassipes) is effective in cleaning up contaminant (heavy metals) in water and determine the highest concentration of heavy metal absorption by the water hyacinth.

II. Materials And Methods

2.1 Preparation of the stock solutions

Stock solutions of 5mg/L for Zn, 6mg/L for Cu and 6mg/L for lead (Pb) for pH 4.40, 7.90 and 8.20 respectively were prepared in distilled water with analytical grade $ZnSO_4$, $PbCO_3$ and $CuSO_4$. 5mg of $ZnSO_4$ was weighed into 1litre volumetric flask and later dissolved with distilled water. Also 6mg of Pb_2CO_3 was weighed into 1litre volumetric flask and later dissolved with distilled water. Also 6mg of $CuSO_4$ was weighed into 1 litre volumetric flask and also dissolved with distilled water and made up to the mark [13].

2.2 Pollution of water and sample collections

Ten (10) medium size plants (E. Crassipes) were placed in each 40 litres plastic tank containing bore – hole water supplemented with the prepared stock solution and placed under screen house. Plant in only bore-hole water tank served as the control. At the end of each week, the plants (E. crassipes) were harvested and further analyzed for metal accumulation. Also bioconcentration factor was determined and finally water samples were collected for water analyses each week. The plants that were harvested were analyzed for Zn, Cu and Pb using Atomic Absorption spectrometer with the model Buck 210VGP [13].

2.3 Digestion of the plant (E.crassipes)

0.2g of (E. crassipes) was weighed into a dry digestion tube. Then 5ml of 2:1 nitric acid to perchloric acid was added to it. Small glass tunnel was thereafter inserted into the digestion tube to act as a reflux condenser and later left for few hours with a temperature of 50^0C. The tube was placed in heating block and digested for one hour at a temperature of 150^0C and later increased to 230^0C.

The time where all tubes got to the densed white fume slope was observed and the digestion continued for 30 minutes. Thereafter, the tubes were removed from digestion block and later cooled at 100^0C. 1ml HCl was added to dispel the last trace of oxides of nitrogen. Thereafter, the tubes were removed from the digestion block and cooled. Then, 5ml of water was added to it. Perchloric was also added to it and were mixed thoroughly. Furthermore, the tubes were allowed to stand until silica was settled. After, the digest was pipetted from the top of the solution leaving the silica sediment undisturbed for analysis and thereafter, sulfur was then determined by turbidimeter as described in a separate section before heavy metals like Cu, Pb and Zn was thereafter determined from the extraction [14].

2.4 Analysis of the sample using Atomic Absorption Spectrometer (AAS)

Prior to AAS analysis, samples was digested to ensure accurate analyte measurement .The sample was injected into the AAS with the use of autosampler.Thereafter, the atomizer aspirated the sample into the light path where it was illuminated by a hallow cathode lamp (HCL) which emitted light at the wavelength characteristic of the desired elements. A built-in detector measured the light emissions both in the presence and absence of the sample and the ratio absorbance was used to determine the analyte concentration.

2.5 Determination of bioconcentration factor

The bioconcentration factor is a measure of bioaccumulation of heavy metals. It was calculated by dividing the trace element concentration in plant tissues (ppm) at harvest by the initial concentration of the element in the external nutrient solution (ppm) [15].

$$Bcf = \frac{\text{Concentration of metal in plant tissues}}{\text{Concentration of metal in water}}$$

2.6 Statistical Analysis

T-test (SPSS-14) was used to determine the statistical significance such that independent sample was used for finding the mean difference of each parameter control with plants and water [16].

III. Results And Discussion

Tables 1, 2 and 3 show the results of the mean concentration of Zn, Cu and Pb absorbed by water hyacinth respectively. The concentration readings in part per million of each heavy metal during the phytoremediation process which were observed for 8 weeks are represented in figures 1, 2, 3, 4, 5, and 6. The figures showed the accumulation of concentrations of Zn, Cu and Pb. As illustrated in figures 1, 2, and 3, there were much differences between the control and the concentration of the heady metals in plants and water throughout the 8 weeks of remediation.

At the end of the 8 weeks, heavy metals (Zn, Cu, Pb) in the water were below the detection limit and the concentrations in the plant increased. It also showed that all the heavy metals were absorbed by water hyacinth which started decreasing from week 1 to week 8. The control of Zn was below the detection limit but the studied concentration decreased from 0.28 to BDL which is within the range of WHO standard (3mg/l) and this observation agrees with the study of Felix et al. [13] on phytoremediation of heavy metals in aqueous solution. Also, Cu concentration decreased from 0.11 to BDL which conforms with the range of WHO standard (2mg/l) and its control was below detention limit. This also agrees with the study of Felix et al. [13]. The concentration of Pb decreased from 0.13 to BDL which also falls within the range of WHO standard (0.01mg/l) while its control was BDL throughout the weeks of remediation..

Figure 1 shows the concentration of Zn absorbed by the plant at each week of observation. In the figure, the plant absorbed much concentration of Zinc in week 3 with 1310mg/kg. Also figure 2 shows that the concentration of Zn in the control water was completely cleaned up such that the concentration of Zn was below the detection limit.

Figure 3 shows the concentration of Cu absorbed during the 8weeks of observation and it was found that the plant absorbed much concentration of Cu in week 3 with 60mg/kg. Also figure 4 shows the concentration of Cu in the water after been absorbed by the plant and it was found that before week 8, the concentration was below the detection limit.

Also figure 5 shows the concentration of Pb absorbed by the plant during the 8 weeks of observation and it was found that the plant absorbed much concentration of Pb in the first week with the concentration of 47mg/kg. Figure 6 shows the concentration of Pb present in the test solution after been absorbed by the plant and it was found that before the completion of the 8weeks of remediation, the concentration was reduced from 0.13 to BDL which is below the detection limit.

The bioconcentration factor values of Zn, Cu and Pb were also calculated and obtained for the 8 weeks of observation. For Zn, the values were 2688, 3849, 3743, 1550, BDL, 4873, BDL and BDL. For Cu, the values were 1350, 207, 2435, BDL, BDL, BDL, BDL, BDL also, for Pb the values were 336, 82, 830, BDL, BDL, BDL, BDL, BDL. These results agree with the study of Zayed et al., [15] on phytoaccumulation of trace element by wetland plant. This implies that the plant had effect on the test solutions by cleaning all the heavy metals present in it because at the end of the 8 week, they were below the detection limit.

IV. Conclusion

Heavy metal uptake by E. crassipes using phytoremediation technology seems to be a prosperous way to remediate heavy metal contaminated environment. It has been proven to have the most effective approach to alleviate the environmental toxic substances associated with contamination. It has some advantages compared with other commonly used conventional technologies. Several factors must be considered in order to accomplish a high performance of remediation result. The most important factor is a suitable plant species E. crassipes which can be used to the uptake ocontaminants. Even the phytoremediation technology seems to be one of the best alternatives. Although it also has some limitations but prolong research needs to be conducted to minimize this limitation in order to apply this technique effectively.

Table 1: Result of the accumulation of zinc absorbed by water hyacinth

Sample	Rep	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
PLANT Control	1	452.00	405.01	411.00	406.00.	402.00	327.00	387.00	411.00
	2	439.50	418.12	402.00	387.00	402.00	356.00	394.00	407.00
	Mean	445.75	411.57	406.50	396.50	402.00	341.50	390.50	409.00
Zn Conc.	1	759.50	896.32	1380.00	984.65	924.00	764.00	586.00	11.48
(mg/kg)	2	745.50	874.00	1240.00	100.42	956.00	698.00	609.00	9.87
	Mean	752.50	885.16	1310.00	542.53	940.00	731.00	597.50	10.68
WATER									
Control	1	0.09	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	2	0.08	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Zn Conc.	Mean	0.085	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	1	0.27	0.24	0.14	0.04	BDL	0.01	BDL	BDL
	2	0.29	0.22	0.11	0.03	BDL	0.02	BDL	BDL
	Mean	0.28	0.23	0.125	0.035	BDL	0.015	BDL	BDL

Where: BDL= Below Detection Limit

Table 2: Result of the Accumulation of Cu absorbed by water hyacinth

Sample	Rep	week	Week	Week	week	week	Week	Week	week
	1	1	2	3	4	5	6	7	8
PLANT	1	20.00	10.50	20.83	18.96	18.17	21.62	16.94	17.94
Control	2	18.50	9.64	23.16	20.14	18.99	19.65	16.35	18.30
	Mean	19.25	10.07	21.99	19.55	18.53	20.64	16.65	18.12
	1	52.00	15.00	64.23	58.91	56.77	44.96	54.43	51.84
Cu conc.	2	56.00	13.98	57.52	58.04	58.41	49.18	56.37	55.32
(mg/kg)	Mean	54.00	14.49	60.88	58.48	57.59	47.07	55.4	53.58
WATER	1	0.10	0.01	BDL	BDL	BDL	BDL	BDL	BDL
Control	2	0.11	0.02	BDL	BDL	BDL	BDL	BDL	BDL
	Mean	0.11	0.02	BDL	BDL	BDL	BDL	BDL	BDL
	1	0.04	0.07	0.03	BDL	BDL	BDL	BDL	BDL
Cu conc.	2	0.03	0.07	0.02	BDL	BDL	BDL	BDL	BDL
(mg/L)	Mean	0.04	0.07	0.03	BDL	BDL	BDL	BDL	BDL

Where: BDL= Below Detection Limit

Table 3: Result of the mean concentration of Pb by water hyacinth

Sample	Rep	week	Week	Week	week	week	week	Week	week
		1	2	3	4	5	6	7	8
PLANT	1	33.79	19.50	20.00	17.44	19.01	19.19	13.86	20.11
control	2	31.85	21.22	22.40	19.76	17.83	18.04	14.21	18.96
	Mean	32.82	20.36	21.20	18.60	18.42	18.62	14.04	19.54
	1	46.50	35.00	38.75	38.22	33.66	31.42	31.42	33.66
Pb conc.	2	48.30	38.44	44.21	4421	37.14	34.81	34.81	37.14
(mg/kg)	Mean	47.40	36.72	41.48	41.48	35.12	33.12	33.12	35.40
WATER									
Control	1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Mean	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Pb conc.									
	1	0.12	0.10	0.05	BDL	BDL	BDL	BDL	BDL
(mg/L)	2	0.14	0.80	0.05	BDL	BDL	BDL	BDL	BDL
	Mean	0.13	0.45	0.05	BDL	BDL	BDL	BDL	BDL

Where: BDL= Below Detection Limit

Table 4: Result of bioconcentration factors of Zn, Cu and Pb

No. of weeks	Zn	Cu	Pb
1	2688	1350	365
2	3849	207	82
3	3743	2435	830
4	1550	BDL	BDL
5	BDL	BDL	BDL
6	4873	BDL	BDL
7	BDL	BDL	BDL
8	BDL	BDL	BDL

Where: BDL= Below Detection Limit

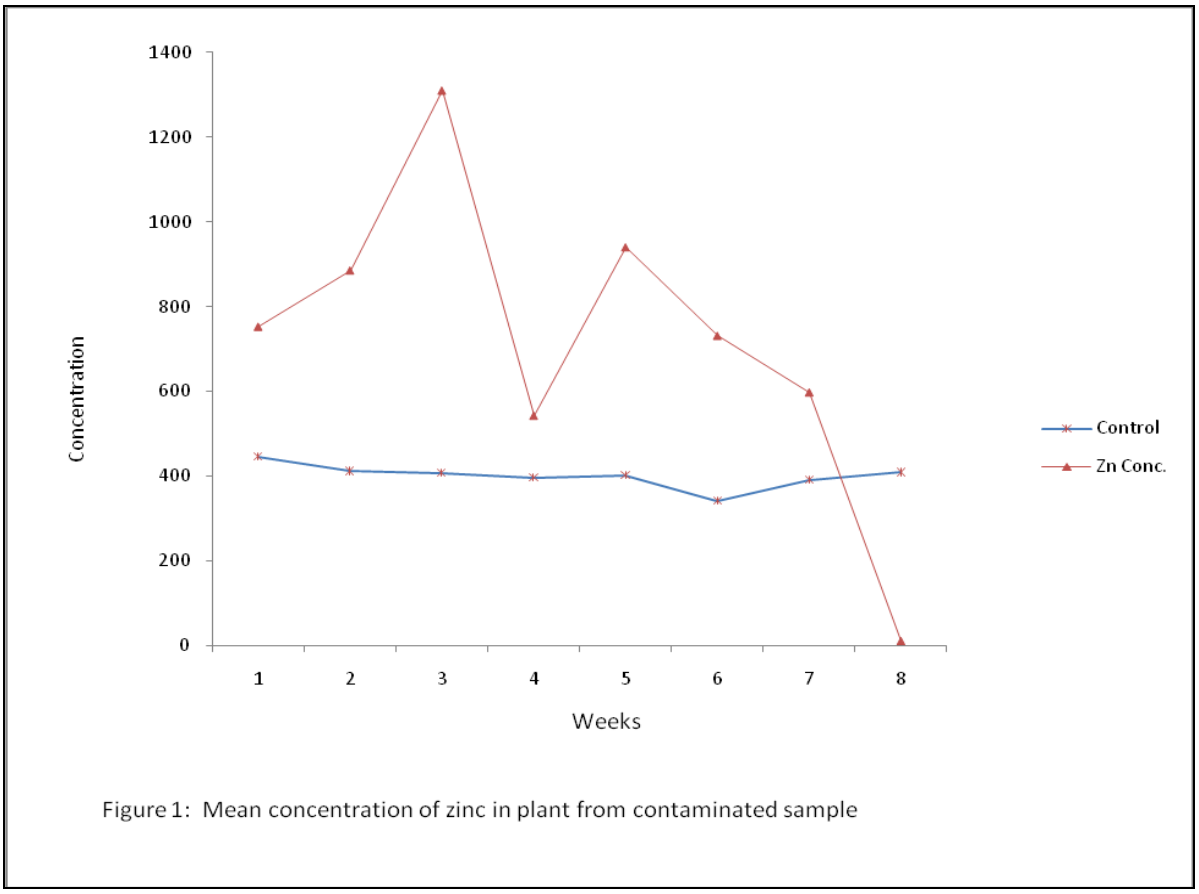

Figure 1: Mean concentration of zinc in plant from contaminated sample

Concentration (mg/kg)

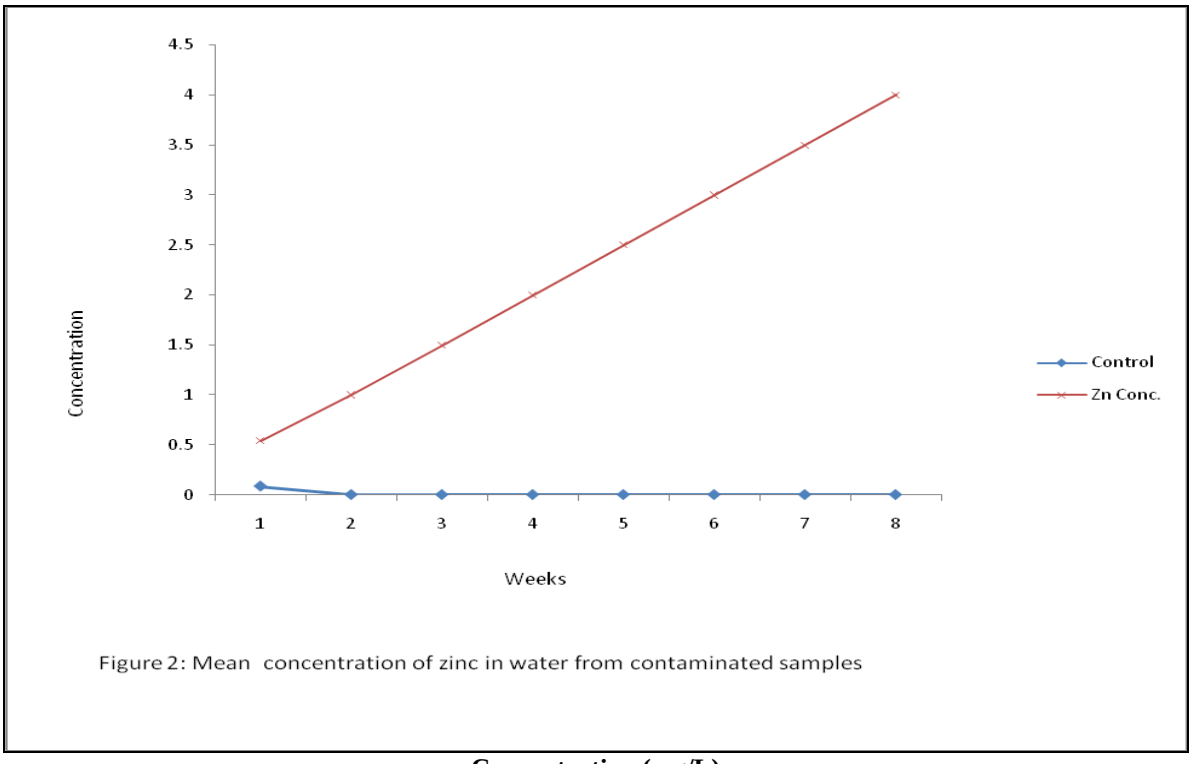

Figure 2: Mean concentration of zinc in water from contaminated samples

Concentration (mg/L)

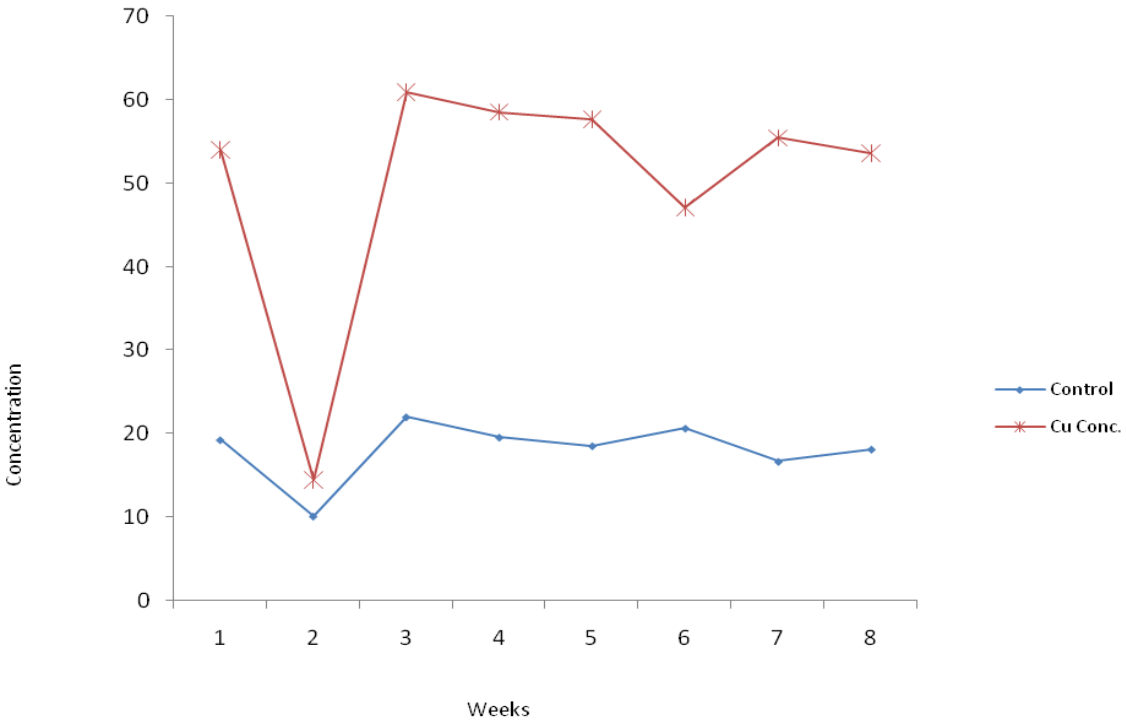

Figure 3: Mean concentration of copper in plant from contaminated sample

Concentration (mg/kg)

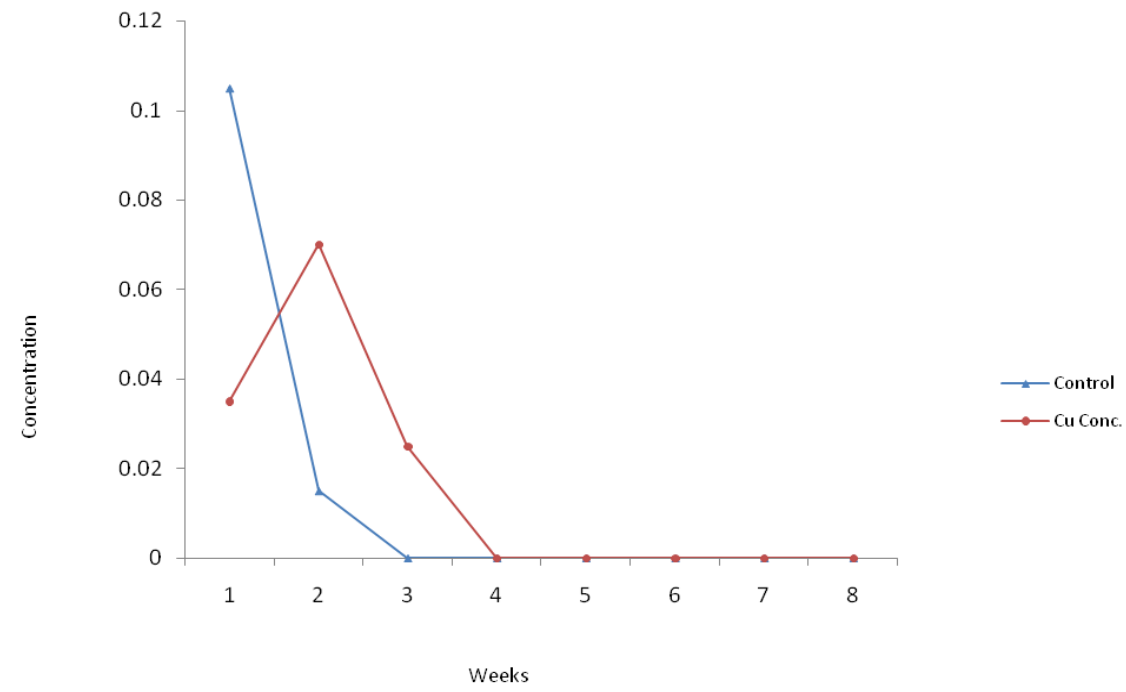

Figure 4: Mean concentration of copper in water from contaminated sample

Concentration (mg/L)

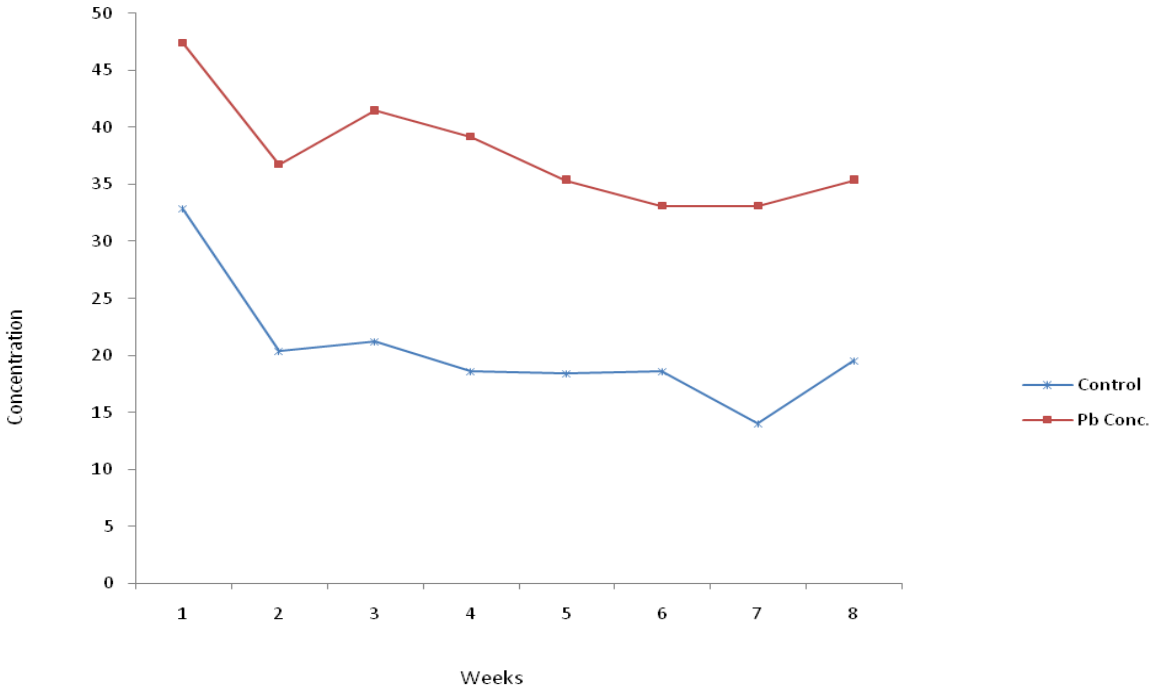

Figure 5: Mean concentration of lead in plant from contaminated sample

Concentration (mg/kg)

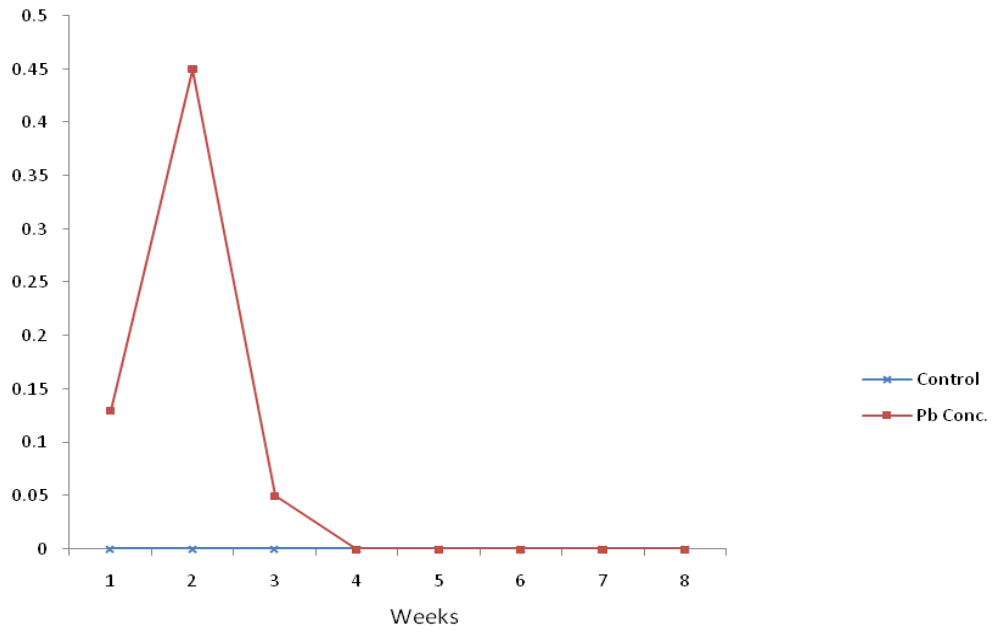

Figure 6: Mean concentration of lead in water from contaminated sample

Concentration (mg/L)

References

[1]. Elde L., Mezosi G., Mess I., Vaes F, Foglen and l. bulik 2000. A phytoremediation as a program for decontamination of heavy metal polluted environment acta biolopca szegediensis 75-76.
[2]. Ndimele P.E 2010. A review on the phytoremediation of petroleum hydrocanbion Pal. J Bipo Sci 715-7212
[3]. Raver O. R Cencil, G. M Beon, M. Dantas and P Jian, 2003. Trace element concentratin in fresh water mussels and macrophytes as related to those in the environment.s.himnol.62:61-70.
[4]. Bower, H. 1979. Journal on heavy metals in the sediment of foundary cover cold spring new York environent 683-689.
[5]. Pehivan, E. Ozkan, A.M Dinc S. and Palayia, S. 2009. Absorption of Cu_2^+ Pb ion our Journal of hazardous materials 167,1-3,1049.
[6]. Raskin I. 1996. Plant genetic engineering may helps with environment clearing pro. C. N at alad sci.93:3164-3166.
[7]. Sinhas Herat R.K and Tendon P.K 2004. Phytoremediation role of plants in contaminated site manapement in book of environmental bioremediation technologies 315-330.
[8]. Murany A. and I. Kodoboc 2008. 2 heavy metal uptake by plant in different phytoremediation treatment in proceeding of the 7th alps-adria scientific workshop staralesna Slovakia pp 55-60.
[9]. Prasad M.N.V and Oliveria Fretas H.M.DE 2003. Metals hyperaccumulation in plants-
[10]. biodiversity prospecting for phytoremediation technology electronic journal of biotechnology vol6,3, 110-1146.
[11]. Maine M. Sune, Hadad N. Sanchez, H. Bentto, G. C. 2006. Nutrient and metal removal in a contributed wetland for water treatment from a metallurgie industry/Ecological engineering pp 26-30.
[12]. UKA, U.N and K.S Chukuka 2007. Effect of water hyacinth infestation on the physio-chemical characteristics of awba reservoir Ibadan sourth-west Nigeria bio.sci.7:282-2787.
[13]. Ehel Mathias et al Evangele, MW; Schaetter. A 2007. Cyande phytoremediation by water hyacinth (eichornia crassipes) chemosphere European commission. Heavy metals in waste final report project pp 3-5.
[14]. Felix, A ,Oluwole, F and Eki, T. 2010:journal on phytoremediation of heavy metals in aqeous solution.pp 49-60.
[15]. APHA, 1985: Standard methods for the examination of water and waste water:Toxicity test method for aquatic organism;16th edn American public health association.pp 1286.
[16]. Zayed, A ,Growthaman, S and Terry ,N. 1998: Phytoremediation of trace element by wetland plant. Environ. quality, pp 715-721.
[17]. Norusis M.J 1993. Spss for windows professional statistic 6.1 spss in Chicago.
[18]. Oyero O. E 1998. Industrial sources and distribution of heavy metal and then biological effect on estuacine animal pp 100-150.