Effectiveness of *Chromoleaeceaeodorata* (siam weed) for Phytoremediation of Lead and other Toxic Metals in Enyigba Lead Mines, Nigeria

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Abstract: Phytoremediation which is environmentally friendly, cost-effective, and aesthetically pleasing process was used to clean up a mapped out 50m by 50m portion of Enyigba mineusing *Chromoleaeceaeodorata*. The concentrations of lead and other toxic metals in the soil wasanalysed using X-ray Fluorescence (XRF) to reveal the current metal loads in Enyigba soil and their corresponding pollution indices (PI). Sequential extraction was done to ascertain the bioavailability of lead and other metals in different part of the mines. *Chromoleaeceaeodorata*was planted for phytoremediation process and was monitored for 24 weeks. Samples of soil (top and sub) and plant (leaves and roots) were collected at fortnight interval and analyze for lead and other metals. The bioaccumulation factors (BAF) and translocation factors (TF) were used to evaluate the phytoremediation process.High values of the Bioaccumulation Factor (4.5) for Cd and Translocation Factors of Pb(8) and Zn (3)were observed. The results revealed that the concentrations of Pb, Zn and Cd were significantly reduced after the phytoremediation experiment. The percentage decontamination of the metals decreased in the order Cd (100%) >Pb (85%) >Zn (75%) by *Chromoleaeceaeodorata.*

Keywords: *Chromoleaeceaeodorata,* Bioaccumulation Factor, Translocation Factors, Phytoremediation, Toxic Metals, Enyigba

Introduction

Increasing industrialization is always associated with distribution of toxic metals from their natural deposits to other part of the environment (Ademoroti, 1996). Mining is a classical pathway of soil lead and other toxic metals are transferred from point source to other part of the environment. Biochemical processes can mobilize lead in the soil to pollute water supplies and impact on food chains which ultimately will affect man. Lead like other metals are non-biodegradable and in human body can accumulate in the body organs especially the brain, which may lead to poisoning (plumbism) or even death as was witnessed in Zamfara State, Nigeria (Leislie, Independence news, 4th June, 2010). Other health challenges associated with lead includeloss of memory, nausea, insomnia, anorexia, weakness of the joints gastrointestinal tract, kidneys, and central nervous system, impaired development, lower IQ, shortened attention span, hyperactivity, among others (ATSDR, 1993; Berti and Cunningham (1997).

Phytoremediation is an emerging technology that employs the use of higher plants for the cleanup of contaminated environments (Boyd and Martens, 2003). To study phytoremediation process, bioaccumulation and translocation factors are useful parameters considered. Bioaccumulation factor is defined as a ratio of metal concentration in plant shoot to extractable concentration of metal in the soil (Branquinnho*et al.,* 2007). For a plant to be an efficient phytoremediation agent, the BAF > 1 is expected. Mathematically, BAF is expressed as $BAF = C_{root} / C_{soil}$. Translocation factor is the plant's ability to translocate heavy metal from root to harvestable aerial part (Reeves, 2003). When TF >1 is obtained, it indicates a preferential partitioning of metals from soil to root and from root to shoot respectively. Mathematically, TF is expressed as $TF = C_{shoot} / C_{root}$. Where C_{shoot} and C_{root} is the concentration of metal in shoot and root respectively (Baker and Whiting, 2002). This study focused on investigating the uptake and bioaccumulation of Pb, Zn and, Cd in lead contaminated environment. This work, therefore, surveyed the extent to which lead and other toxic metal has contaminated or polluted the soils and plants grown within the vicinity of the lead – zinc mine in Ebonyi State, Nigeria. But most importantly, it studied the extent at which *ChromoleaeceaeOdarata*can be used as phytoremediation agent to clean up a selected study area of Enyigba mine.

Materials and Methods

First phase experiment

The current data of lead and other heavy metal load in anthropogenically active areas of Enyigba lead - zinc derelict was obtained. This was done by collecting composite soil samples at 0-30 cm (n=6) and at 60-90 cm (n=6) depths from each sampling site,. The former represents the top soil while the later represents the sub soil (Danish EPA, 2000). The soil samples will be air-dried, ground mechanically with stainless steel soil grinder and sieved to obtain < 2 mm fraction. 30 g sub-sample was drawn from the bulk (< 2 mm fraction) and reground with laboratory mortar and pestle to obtain < 200 µm fraction. The samples will be further dried in an open inert vessel in a muffle furnace at 105 ^{o}C for 2 hours so as to remove soil moisture, after which the samples will be cooled in desiccators (FAO, 2009). The pre-treated soil samples were analyzed using X-ray Fluorescence (XRF) analysis at the Centre for Research and Development (CERD), ObafemiAwolowo University Ile Ife, Nigeria. The result of this first phase of this work has been published. (Oti *et al.,* 2017)

Second phase Experiment

Soil parameters such as pH; percentage silt, clay and sand; organic matter were investigated using Orion 920A pH meter with deionized water (Klute, 1986); Hydrometer method (Brown, 2007) and Walkley and Black method (White, 2006) respectively. From the soil analysis, it was discovered that the highest concentration of lead was found in a farm near the mine. Total concentration of a metal in soil to an extent reveal the level of contamination of the metal, however, it does not give any insight into the metal's bioavailability or mobility. Hence, there was a need to examine the physicochemical forms in which the metals in the soil exist so as to have a better understanding of the state of the metals and their availability for absorption by plant roots in the soils. Consequently sequential extraction of heavy metals was carried out. The distribution of heavy metals in the soil samples were carried out following the procedure prescribed by Tessier *et al.,* (1979); Alba *et al.,* (2005) and Okoro*et al.,* (2012).

Fraction 1(Exchangeable fraction): 1g of (dry weight of < 2mm sieved soil sample was treated with 45 mL of 1M ammonium acetate (pH=5) with acetic acid by stirring for 1 hour under continuous stirring. After centrifugation, a residue was obtained.

Fraction 2 (Metals bound to carbonate): the residue obtained from step 1 was stirred for 4 hours with CH_3COONa/CH_3COOH solution at pH = 5 and after centrifugation, a residue was obtained.

Fraction 3 (Bound to Fe-Mn Oxide): residue from step 2 was treated with 0.04M NH_3OHCl solution in 25% CH_3COOH (v/v) and was stirred for 6 hours at 96^{o}C until all the free Fe-Mn Oxides were completely dissolved.

Fraction 4 (Residue Fraction or metals bound to silicates): the last residue was mineralized using HNO_3/H_2O_2 and digested using HF and $HClO_3$. Heavy metal concentrations were determined in all steps by Atomic Absorption Spectrophotometry *(Buck Scientific VGP 210 model)*. The results of this second phase of this work has been submitted for publication in the EBSU journal of Nature

Third phase Experiment

The pilot study was carried using 50m by 50m after obtaining the community approval and some youths of the community were engaged for menial duties such as clearing of bushes, levelling of the soil, security and day to day agronomic activities of the site. The plant used as phytoremediation agent was *Chromoleaeceaeodorata*(siam weed). Planting of the weeds was done in the first week of April 2017 using agricultural standard during the beginning of rainy season. Irrigation system was used periodically at the early stage of the growing season to supply water. At the beginning of the experiment, weekly monitoring of the plants was done by a native to evaluate the health of the plant. However after four weeks, soil and plant samples were collected every one month for six month and the levels of metals in the samples were evaluated using AAS. This was done to indicate the uptake performance of the phytoremedition agent, *Chromoleaeceaeodorata* (siam weed). The concentration of lead and few selected heavy metals in the soil and plants were recorded and the statistical analysis was done using One way analysis of variance (ANOVA). The findings of this research was made public via radio program to sensitize the public on the toxicity of lead to human health and need for phytoremediation as a tool to clean up the affected areas

Results

Table 1: Levels of Pb, Zn and Cd in soil, stem and leaf samples from Enyigba Mines and

	Mean concentration before Experiment (ppm)			Mean concentration after Experiment (ppm)		
Metal	Soil A	Stem A	Leaf A	Soil B	Stem B	Leaf B
Pb	0.20±0.07	0.02±0.01	0.16±0.06	0.03±0.02	0.00±0.00	0.13±0.05
Zn	0.04±0.02	0.01±0.01	0.03±0.02	0.01±0.01	0.01±0.01	0.02±0.01
Cd	0.09±0.04	0.02±0.01	0.01±0.01	0.00±0.00	0.01±0.01	0.01±0.01

Table 2: Bioaccumulation Factors (BAF = $\frac{Cstem}{Csoil}$) and Translocation factors (TF = $\frac{Cleaf}{Croot}$) of Pb, Zn and Cd in *Chromoleaeceaeodorata*and Percentage Decontamination (% Dec = $\frac{CsoilA - CsoilB}{CsoilA}$x 100)

	Before Experiment		After Experiment		
Metal	BAF	TF	BAF	TF	% Dec
Pb	0.10	8.00	0.00	-	85
Zn	0.25	3.00	1.00	2.00	75
Cd	4.50	0.50	-	1.00	100

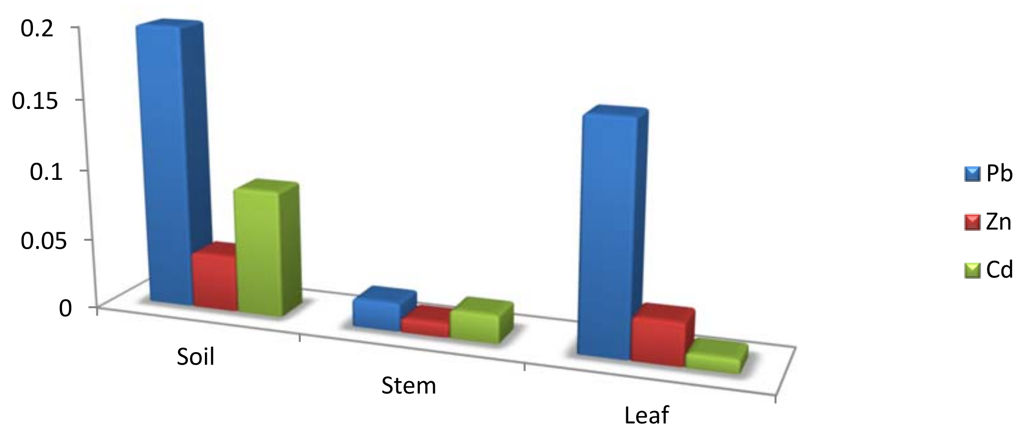

Figure 1: Level of Pb, Zn and Cd in Soil, Stem and Leaf before Experiment

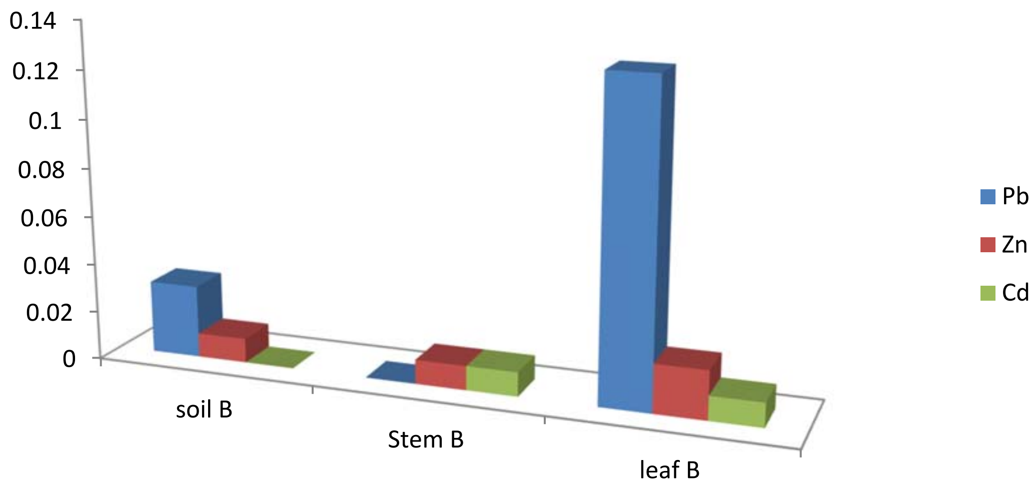

Figure 2: Levels of Pb, Zn and Cd in Soil, Stem and Leaf after Experiment

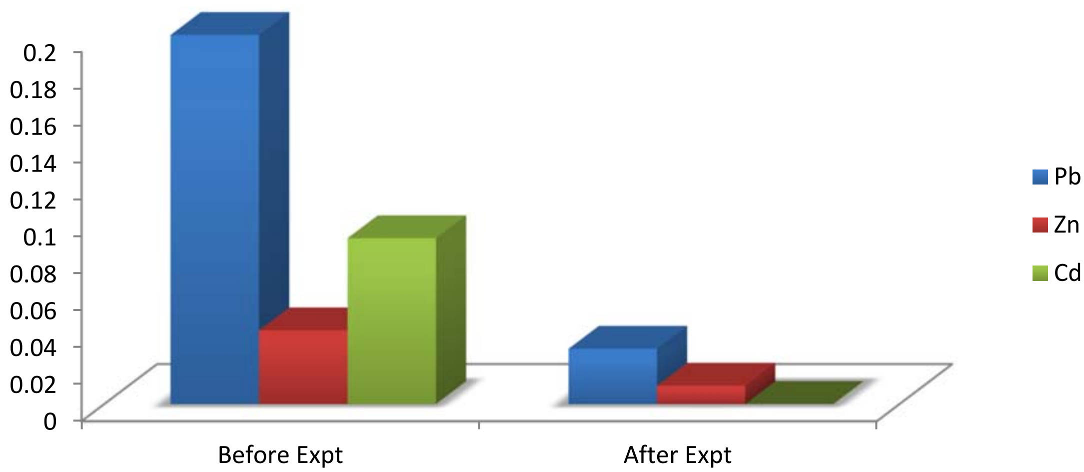

Figure 3: Levels of Pb, Zn and Cd before and after Experiments

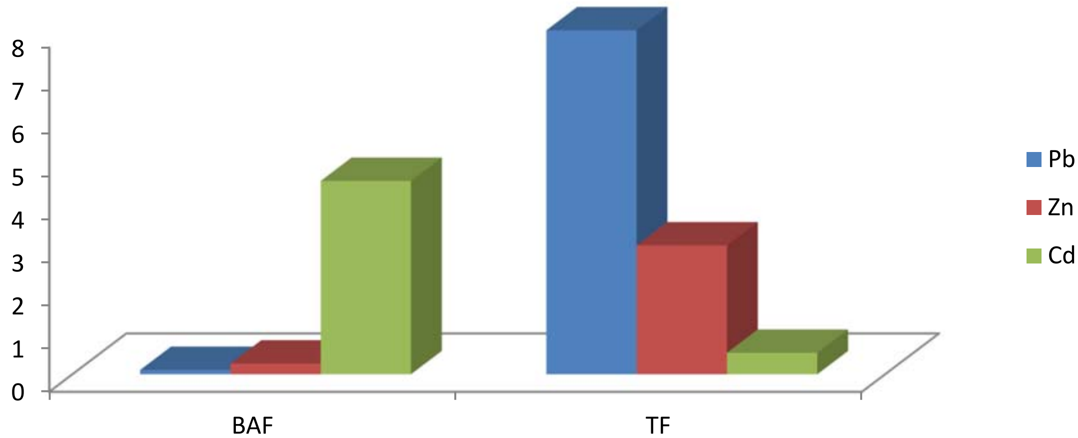

Figure 4: Bioaccumulation Factor and Translocation Factor of Pb, Zn and Cd

Discussion

Table 1 revealed that Pb was present in Enyigba soil before the experiment and also in the stems and leaves of *Chromoleaeceaeodorata*used for phytoremediation. The concentration of the metals were found in the order Pb>Cd>Zn. Statistical analysis of the data showed that the level of Pb before the phytoremediation experiments were significant higher than Zn and Cd at $p < 0.05$. Table 1and Figures 1 and 2 revealed that the concentrations of Pb, Zn and Cd significantly reduced after phytoremediation experiment. Table 2 showed that the percentage decontamination of the metals decreased in the order Cd (100%) >Pb (85%) >Zn (75%). This means that *Chromoleaeceaeodorata*was able to remove from the soil the entire Cd, 85% of Pb and 75% of Zn. The reason for the ability of *Chromoleaeceaeodorata* to remove these metals can be explained by the high value of the Bioaccumulation Factor (BAF) for Cd which was 4.5 and Translocation Factors (TF) of Pb and Zn which were 8 and 3 respectively (Figure 4). High BAF and TF are useful parameters that indicate the potential of a plant to remove toxic metals from the environment. While BAF is the ability of the plant to accumulate the heavy metals with respect to the metal concentration in the ecosystem, TF is the plant's ability to translocate heavy metal from root to harvestable aerial part. For a plant to be an efficient phytoremediation tool in the contaminated soil, the BAF and TF have to be higher than one (Wong, 2000; Brown *et al.,* 1994). When values of BAF>1 and/or TF >1 is obtained, it indicates a preferential partitioning of metals from soil to root and from root to shoot respectively (Baker and Whiting, 2002; Branquinho*et al.,* 2007).

Conclusion

The values of TF and BAF of the studied *Chromoleaeceaeodorata* are strong indices of their phytoremediation ability to remove Pb, Zn and Cd (Baker and Walker, 1990). The productivity of every nation depends on the health of the work force. In simple terms, when the health of aEnyigba community is threatened by the presence of lead in the environment, it will ultimately affect the masses that consume food produced from this Enyigba area. This work establishes the fact that with the right plants lead contaminated area will be clean up using *Chromoleaeceaeodorata*.

Recommendation

The following are recommended based on the findings of this research:

- Food coming from Enyigba environment should be investigated for lead contamination before consumption
- Adequate guidelines to be provided by the government for miners to minimize release of pollutants into the farmlands and water bodies
- There is need for effective regular monitoring program to be put in place to determine level of toxic metals in the mining environment from time to time
- Farmers may need clearance from the government agencies before cultivating the arable lands around the derelict
- To clean up lead environment, *Chromoleaeceaeodorata*has proven to be an effective phytoremediation agent with 85% success rate within six months

- The cost of phytoremediation of lead is far below other methods used to clean up a lead contaminated environment, hence it has to be encouraged at all levels.
- There is need for further researches in phytoremediation of lead in Enyigba mines using other non edible grasses and weed

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