IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 7 Issue 3, March 2020
ISSN (Online) 2348 – 7968 | Impact Factor (2019) – 6.248
www.ijiset.com

Analysis of the Treatment of Heavy Metals Contaminated Soils Obtained From Open Dumpsites Using Phytoremediation Technique

L. Uyigue* and Achadu, M. Abah

Department of Chemical Engineering, University of Port Harcourt, Port Harcourt, Nigeria.

ABSTRACT

This study was focused on measuring the potentials of fluted-pumpkin and waterleaf plants to removing heavy metals from contaminated soils collected from near dumpsites using phytoremediation technique within a 50-Day study period. This technique is generally envisaged to be simple to apply, efficient and cost-effective. The choice of using edible plants to serve as test plants for the study was also to help strengthens the regulations on phytoremediation treatments. To achieve these objectives, soil samples collected from designated distances near the Woji-railway and Eliozu dumpsites were prepared into several experimental pots (including control soil samples), while the selected test plants (fluted-pumpkin and waterleaf) were planted into the respective pots amidst regular irrigation, monitoring and measurements. The results obtained showed gradual reduction in heavy metals content of the cultivated soils in the experimental pots, for which Cr concentration reduced from 26.98 and 24.68 mg/kg (at Day-0) to 15.32 and 17.42 mg/kg (at Day-50) for soils collected near Woji-railway and Eliozu dumpsites respectively. A similar trend was also reported for the other detected heavy metals in the soils. Adequate uptake potentials for heavy metals in contaminated soils were observed for the cultivated test plants (fluted-pumpkin and waterleaf) during this study. This was evident in the moderate percentage reduction ($\leq$ 43 %) for all heavy metals detected in the soils during the treatment (except for Cd which had 72 %.). There was also the observed low to moderate concentrations in the distribution of detected heavy metals in the plant system (i.e. in leaves and roots+shoots), which was evident in the measured bioaccumulation factors, for which Cd had the highest value of 0.36.The test plants growth profile (within the 50-day study period) showed normal physiological characteristics, which is an indication of high resistance of test plants to the impact of the contaminated soils. To avoid heavy metals infiltration into the ecosystem's food chain, regulatory agencies should further strengthen the prohibition of cultivating edible and grazing plants near open dumpsites.

Keyword: Heavy metals, open dumpsite, phytoremediation, test plant, bioaccumulation factor

1. INTRODUCTION

The term heavy metal is referred to as a metallic element which possesses multiple valences, and has moderately high density and high atomic mass. It is somewhat reactive and can be toxic (or poisonous) to humans even when exposed to trace concentrations of the metal (Phipps, 1981). Heavy metals are largely in abundance and they are also numerous. In the periodic table, they account for about 99 elements out of the 118 identified as building blocks of our universe. These metals occupies the space between group 2 and 3 (as transition metals), and lies on period 4 downward in group 1 and 2; 3 and 7 (as post-transition metals); while the Lanthanides is another heavy metal group having atomic number 57 – 71 (Emsley, 2011).

The major sources of heavy metals are from natural materials such as rocks and ores. But it generations are practically from industrial activities such as mining of minerals, oil and gas production, cement production, metals extraction etc. It can also be found in some physicochemical and biological processes, where it exist in trace concentrations, and may play indispensable roles as can be identified in human organ function (such as respiration, glands, metabolism, vitamins release etc.) and in microbial fermentation. It is also a component part of key technological advancement such as semiconductor device, reaction catalyst, prodegradant in plastics, pigments, leaded petrol etc. (Koller and Saleh, 2018). Mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Ti) and lead (Pb) are typical examples of heavy metals (Duffus, 2002, Duruibe et al. 2007).

Within an environment, heavy metals can distribute or migrate from it source to other locations via physicochemical mechanisms. For example, dissolution, precipitation, ion exchange, adsorption, desorption, etc., are typical mechanisms for heavy metals transfer. Heavy metals can enter into water supply by contact with corroded (or eroded) metal or ceramic pipe channels, or can migrate into surface waters by leaching from a degraded source (e.g. water wells, river beds, open dumpsites etc.). Actual contact of heavy metals with water aquifer is aided by natural forces: capillary, eutrophication and permeation (Achadu et al., 2018). During gas flaring (or in other emissions), heavy metals in the form of suspended particles can migrate into soil and water environments by contact with rainwater (Uyigue and Enujekwu, 2017; Uyigue and Njoku, 2017). Also, plants can synergize with soil microbes to converts the heavy metals in soils into bio-available forms in the plant; it is also called plant uptake or bioaccumulation (Ali et al., 2013; Ghosh and Singh, 2005).

Heavy metals presence in the environment can be generally harmful, especially when in high concentrations. For instance, heavy metals in soil can severely inhibit biodegradation of organic contaminants, while causing reduction in soil fertility. It may pose greater risks (or hazards) to humans if they consume plants or animals that have been bio-enriched with these metals, or to have drank groundwater contaminated with heavy metals (Buekers, 2007). This can have negative impact on the ecosystem; and will in turn interrupt the food chain system (i.e. soil → plant → human or soil → plant → animal → human). Therefore, heavy metals contamination will have direct social-economic impact on the inhabitants: reduction in food quality, reduction in land usability for agricultural production, food insecurity, land tenure problems and health challenges (Kabata-Pendias and Pendias, 2001).

Generally, treatment techniques for soils contaminated with heavy metals varied widely in terms of application, efficiency and cost effectiveness. Gupta et al. (2000) had classified treatment techniques into three categories: (i) gentle in-situ remediation, (ii) in-situ harsh soil restrictive measures, and (iii) ex-situ harsh soil destructive measures. The first technique will help soil regain its functionality, while the last two methods will prevent humans from coming into contact with the contamination.

USEPA (2007) also suggested: (i) source control and (ii) containment remedies as treatment techniques, while the source control method involves in-situ and ex-situ treatments. In-situ treatment removes the contaminant without excavation (or removal) of the soil, while ex-situ treatment excavates or removes the contaminated soils from the site. Another treatment grouping for heavy metal contaminated soils include isolation, immobilization, toxicity reduction, physical separation, and extraction techniques, for which the detailed classifications are shown in Table 1.

Table 1: Treatment techniques for heavy metals contaminated soils (or related media) (USEPA, 2007).

Serial No.	Broad class	Sub-class
1.	Isolation	Capping, sub-surface barriers
2.	Immobilization	Solidification/stabilization/cementation, vitrification, chemical treatment
3.	Toxicity and mobility reduction	Chemical treatment, permeable walls treatment, biological treatment (e.g. bioaccumulation and phytoremediation), bioleaching, biochemical processes.
4.	Physical separation	Sedimentation, filtration, screening etc.
5.	Extraction	Soil washing, pyrometallurgical extraction, in-situ soil flushing, and electrokinetic treatment.

Phytoremediation technique is the main focus of this present study. It actually belongs to the toxicity and mobility reduction group. This method specifically makes use of plants and soil microbes to eliminate, degrade, or immobilize heavy metal contaminations from affected soils, sediments and wastewaters by uptake into the plant system (Ali et al., 2013; Ghosh and Singh, 2005). This approach is cost effective, widely acceptable and environmentally friendly. Its mechanisms for extracting heavy metals from the contaminated environment are very efficient, while the resulting plant residues or biomasses that are rich in heavy metals can be recycled for metals recovery (Liu et al, 2000).

Baseline mechanisms of action for phytoremediation states that the contaminants are first converted into soluble complexes by redox reactions via the aid of plant-produced chelating agents and plant-induced pH conditions of contaminated media. It is then followed by the uptake of these soluble complexes (or ions) into the plant body (i.e. roots, shoots, leaves and fruits). Basic uptake mechanisms for phytoremediation include phytoextraction, phytostabilisation, rhizofiltration, and phytovolatilization. Within the plant body, there also exist transport mechanisms for distributing the heavy metals, namely proton pumps, co-transporters, and protein channels (Phipps, 1981; Tangahu et al, 2011).

Basic factors that are needed for selecting plants with potentials for phytoremediation are presented: (1) nativity of plant species to the ecosystem: meaning, native plant species are more preferred because exotic plants can endanger the ecosystem. (2) Type of plant species: which implies crop species that are less palatable to grazing animals are more preferred than weed species. (3) Level of soil contamination: shallow-rooted plants are more appropriate remediation plant than deep-rooted plant for soils contaminated only at the surface. (4) Level of tolerance of plant to the contamination (Lasat, 2000).

Testing and observing the levels of tolerances of plants to heavy metals exposure is a significant step before the actual phytoremediation trials for heavy metals uptake potentials of plants. In this regard, several studies have been conducted to measure plant responses to heavy metals exposure. Goland-goldhirsh (2006) observed the Chives plants (*Allium schoenoprasum*) to have showed signs of wilting, yellowing and growth inhibition on exposure to 0.25 mM concentrations of Ni, Co and Cd, while Dasgupta et al (2011) reported inhibited seed germination and decreased weight of Chick pea (Cicer arietinum also called garbanzo bean) when exposed to increased Pb and Cr concentrations.

Similarly, Tiecher et al (2016) observed extreme decrease in the dry weight of maize plant (*Zea mays*) on zinc-amended soil with increased Zn doses. Apparently, the increased doses of Zn also changed the chlorophyll-a flourescence and the antioxidant system parameters for the maize plant. On the other hand, Rahman et al (2016) observed that Pea plants exposures to Cd at 20 μM concentration did not to have any significant effect on its growth characteristics both in terms of root dry weight, shoot height, shoot dry weight, leaf number and total chlorophyll concentrations.

Based on similar responses presented above, actual phytoremediation trials have also been reported. For example, the potentials of three macrophyta plants to uptake atrazine herbicide from aquatic environment were tested using an experimental pot. The results showed low potentials for atrazine removal from the aqueous media by the three macrophytes, except for A. Caroliniana and L. Gibba species which demonstrated higher uptake potentials at higher concentration of the atrazine: at above 10 mg/l (Guimarães et al, 2011). Trace metals uptake potentials of the halophyta plants from polluted soils were also tested in Qatar via laboratory experiments. The results showed high uptake capacity (or hyperaccumulation) of heavy metals by the plant (Usman et al, 2018).

Pilipovic, et al (2012) investigated the potentials of cloned poplar plant (populous species) for use in the phytoremediation treatment of crude oil contaminated soils from Petro refinery at Danube-Novi-Sad, Serbia (with total petroleum hydrocarbon, TPH and mineral oils as key contaminants). The results showed high uptake potentials for contaminants by the poplar plant as evident in the physiological evaluations and in the increased weight of biomass leaves and roots harvested from the pots experiments.

In a like manner, Muhammad et al (2013) also investigated the potentials of selected wild plant species: Selaginella jacquemontii, Rumex hastatus, and Plectranthus rugosus) to remove macro and trace metals (MTM) from contaminated soils in localities of Kohistan region, Northern Pakistan using phytoremediation techniques. From the results obtained, test plants showed wide variability in MTM metal uptake from the contaminated soils, indicating multifold enrichment factors (EF) for Fe, Mn, Cr, Ni, and Co as compared to background areas.

Castor cultivars (Ricinus communis) were also used as test plant species for phytoextraction potentials for a 100-day study period using randomized pot experiment. Results obtained showed significant uptake potentials of the plant as evident in the decreased soil heavy metals content (Khan et al, 2019). The effect of amendment of heavy metals contaminated soil on the uptake potentials of Switch grass and Sunflower were also studied. The contaminated soils were respectively amended with organic materials: compost, coir fiber, ethylenediamine tetraacetic acid (EDTA) etc. The results showed detectable levels of heavy metal uptake in the test plants than in the controls (Shrestha et al, 2019; Alabdoudi et al, 2018 and Hasan et al, 2019).

This present study would test the potentials of edible vegetable plants to uptake heavy metals from contaminated soil samples collected from near two open dumpsites which are located in industrial areas in Port Harcourt. The test plants for this study are Fluted-pumpkin (Telfairia occidentalis) and Waterleaf (Talinum Fruticosum). In it, a 50-day study period would be implemented using phytoremediation technique. The pot experiment technique would be adopted, while the growth profiles of the test plants would be assessed within the study period. The recovered plant biomasses would be subjected to heavy metal content analyses. The outcome of these analyses would serve as one of the guides in preventing the migration of heavy metals from the dumpsites into the bodies of the inhabitants.

(a) (b)

Figure 1: Photographs of test plants: (a). Waterleaf; (b). Fluted-pumpkin

2. MATERIALS AND METHOD

2.1 Materials

The main materials used for this study are listed: test plants (Fluted-pumpkin (or Telfairia occidentalis) and Waterleaf (or Talinum Fruticosum)) and soil samples. The test plants were obtained from a research botanical garden at the University of Port Harcourt, while the soil samples were collected from near two open dumpsites in Woji-railway and Eliozu areas in Port Harcourt. Additional materials used for this study include several cylindrical plastic buckets (for pot experiments) of 20 L capacity each (with base and open-top diameters = 25 and 29 cm respectively, and slant height = 32 cm), including plastic hose for irrigation purpose and a hand auger for soil sampling purpose. Others materials, reagents and equipment used for this study would be mentioned at the appropriate sections.

2.2 Method

2.2.1 Sample collection and preparation

Soil samples were collected from locations near Woji-railway and Eliozu dumpsites using hand auger device. For each dumpsite, five sampling points were identified at designated distances away from the dumpsites epicenter: 20 m, 40 m, 60 m, 80 m and 100 m, while another soil sample was collected at 1 km location from the dumpsite to serve as control. The soil samples were collected from each location at 10 cm depth. They were packaged in bags, labeled and transported to the laboratory.

At the laboratory, the soil samples from the different locations for a particular dumpsite were mixed together in order to form a single and consistent soil composite sample. Next, they were sun dried in order to reduce soil moisture content to near equilibrium point. In addition, they were also pulverized in order to increase its porosity. Eight plastic buckets of 20 L capacity each, were separately filled with soil composites from the different dumpsites to serve as treatment pots, and were respectively labeled as WRD1 to WRD4, and ELD1 to ELD4.
The soil samples collected from the control locations for the respective dumpsites were also subjected to similar treatment and preparation techniques. Four control pots were prepared as labeled: CTRL 1 to CTRL 4.

2.2.2 Cultivation of test plants

The fresh fluted-pumpkins and waterleaves were separately planted in the respective experimental pots. Fluted-pumpkin and waterleaf were respectively planted into two experimental pots each, for Woji and Eliozu dumpsites, making a total of eight experimental pots. Similarly, these test plants were also planted each into the control pots for the different dumpsites. Amidst frequent irrigation and close observation, the test plants were allowed to grow for a period of 50 days in an open space near the laboratory, during which the plants growth characteristics (such as shoot height, number of leaves and total chlorophyll content) were routinely measured.

2.2.3 Heavy metals content analysis of soil sample

Samples of soils were routinely collected from the experimental pots as designated, and taken for heavy metals content analysis on intervals of 10 days starting from Day-0 to Day-50. Measurements obtained from control pots were taken as background values.

(A). Acid digestion of soil sample

Prior to heavy metals content analysis, soil samples were first dried to a constant weight at oven temperature of 105°C, grinded into fine powder and were subjected to acid digestion. To achieve this, 2 g of soil sample was weighed into 250 ml clean beaker, while 25 ml HNO_3 (50 % w/w, Sigma-Aldrich) was added for pre-oxidation. It was then set on a heating mantle in a fume chamber assembly for 30 minutes until the cessation of brown fumes was noticed. The beaker was allowed to cool for 5 minutes. Thereafter, another 10 ml HNO_3 (50% w/w, Sigma-Aldrich) was again added, while the content was digested for additional 1 h at controlled heating by mantle. After cooling, 50 ml distilled water was added to the content amidst agitation, and was followed by filtration. The filtrate was collected and used for Atomic Absorption Spectrophotometric analysis (AAS). This procedure was repeated for all soil samples prior to AAS analysis.

(B). Atomic Absorption Spectrophotometer Analysis

Atomic Absorption Spectrophotometer, AAS (Perkin Elmer AAnalyst 200) was the equipment used for the heavy metals content measurements. The measurement requires the direct aspiration of digested soil sample into an air/acetylene flame system. A hollow cathode lamp of specific wavelength generates beams of chromatic light that is characteristic of the metals to be determined. This light is absorbed by the digested sample on passage through the flame. The monochromator and detector system will enable the absorbance to be measured and recorded. The minimum acceptable absorbance from which metal concentrations are detected is estimated at 0.001au. Also, to check for accuracy or drift of measurements, the AAS is calibrated using AccuStandard (or serial calibration standards) prior to each metal determination.

2.2.3 Analysis of plant sample

(A). Growth analysis

The growth parameters that were measured for the test plants in this study include shoot height, number of leaves and total chlorophyll content of leaf.

i. **Shoot height:** This was measured using a ruler. The average values were recorded.
ii. **Number of leaves:** This was physically counted in the plants and was recorded.
iii. Total chlorophyll content: A standard method of measuring chlorophyll content in leaf tissues as recorded in SERAS (1994) and modified in Kamble et al (2015), and as also cited in Oksana et al (2017); Gogoi1 and Basumatary (2018) was adopted for this measurement. In it, fresh leaves from cultivated test plants (Fluted-pumpkin and waterleaf) were harvested and separated on the basis of dumpsite soils and plant type. 0.5 g of leaf samples was separately cut into fine pieces and grinded with mortar and pestle. 20 ml acetone (80 % w/w) and 0.5 g of ($MgCO_3$) powder was added to each mixture while being grinded. The mixtures were separately incubated at 4ºC for 3 h, followed by centrifuging at 2000 rpm for 5 minutes. The separated filtrates (or supernatants) were then diluted to 100 ml with acetone in different 250 ml conical flasks amidst vigorous agitations. Green color liquid extracts were then obtained in the different conical flasks.

5 ml quantity of each extract was placed one after the other in a cuvette, inside the sample chamber of a digital spectrophotometer (LABTRONIC LT-39). Single light beam of wavelengths 645 and 663 nm were incident on samples via the aid of grater (with 1200 lines/mm), and slit-lens arrangement. A silicon photodiode detector was used to measure the amount of absorbance (or transmittance) of samples. The actual reading of absorbance of a sample was taken as mean of triplicate measurements. The chlorophyll-*a*, *b* and total chlorophyll were calculated by formulas as shown in equations 1 - 3:

$$Chlorophyll-a\ (mg/g-tissue) = \frac{(12.7(A663) - 2.69(A645))V}{1000W} \quad (1)$$

$$Chlorophyll-b\ (mg/g-tissue) = \frac{(22.9(A645) - 4.68(A663))V}{1000W} \quad (2)$$

$$Total\ chlorophyll\ (mg/g-tissue) = \frac{(20.2(A645) + 8.02(A663))V}{1000W} \quad (3)$$

Where, A = absorbance at specific wavelength (au); V = final volume of chlorophyll extract (ml); W = fresh weight of leaf tissue extracted (g).

(B). Heavy metals content analysis of plant biomass

Plant biomass from Fluted-pumpkin and waterleaf were harvested after the 50-day study period from the experimental pots as designated. They were then washed with distilled water and were carefully separated into roots, shoots and leaves. The separated parts of the plants were oven dried for 72 h at 105 °C until a constant dry weight was attained. On the basis of the respective dumpsite, the roots and shoots of the harvested test plants were grinded together into powder, while the leaves were also handled separately for fluted-pumpkin and waterleaf.

1 g powder sample of the biomass were each placed in separate falcon digestion tubes, wherein 10 ml HNO_3 (50 % w/w, Sigma-Aldrich) were each added, and allowed to stand for 24 h at room temperature. Thereafter, the digestion tubes were carefully heated on a hot plate until the cessation of red fumes NO_2 was noticed. The tubes were cooled, while 2 ml $HClO_4$ (70 % w/w, Fischer) was added to each tubes, followed by further heating and evaporation to small volumes. The content of each tube was separately transferred to individual 50 ml conical flasks amidst dilution with distilled water. The resulting filtrates of the digested biomass were each subjected to AAS analysis for heavy metals content measurement.

2.2.4 Empirical evaluation of phytoremediation treatment of soils

Parameters used to measure the performance of the soils phytoremediation treatment include enrichment factor (EF), pollution load index (PLI) and bioaccumulation factor (BF).

(A). Enrichment factor, EF: This factor in metals measures the degree or extent of metals accumulation in soils beyond the normal mineralogical characteristics of the soil in focus. In other word, it is a measure of soil contamination. Empirically, it is estimated as the ratio of actual concentration of metal in the soil to that of its background concentration (Barbieri, 2016), as shown equation 4.

$$EF = \frac{metal\ in\ soil\ sample}{Background\ value}. = \frac{Metal\ in\ soil\ sample}{Metal\ in\ control\ sample} = \frac{c_e}{c_b} \qquad (4)$$

Where, EF = enrichment factor, c_e = concentration of metal in soil sample, mg/kg
c_b = concentration of metal in control sample, mg/kg.

(B). Pollution load index, PLI: This parameter gives summative assessment of the overall of level of heavy metal pollution in an environment. In other word, it is a measure of the extent or degree by which heavy metals in soil exceeds its background concentration (Rabee et al, 2011). Empirically, it is the n^{th} root of the geometric summation of enrichment factors for all the heavy metals present in the soil sample.

$$PLI = \left(\prod_{i=1}^{n} EF_i\right)^{1/n} = (EF_1.EF_2.EF_3.EF_4...............EF_n)^{1/n} \qquad (5)$$

Where, EF_i = Enrichment factor for i^{th} metal, n = number of metals identified and measured.

(C).Bioaccumulation factor, BF: Measures amount of uptake of unwanted materials by a living thing (especially plant) from a substrate. In other word, it is a parameter that measures plant uptake capacity for contaminants in soils, sediments and wastewaters. Also, note that BF measures contaminated soils treatment performance by pytoremediation.

$$BF = \frac{conc.\ of\ \ metal\ \ in\ \ plant}{conc.\ of\ \ \ metal\ \ is\ soil} \qquad (6)$$

3. RESULTS AND DISCUSSION

The results obtained from this study are shown in Tables and Figures, and will also be discussed in the following subheadings: (i) Dumpsite interaction with nearby soils; (ii) Profile of heavy metals content reduction in cultivated soil samples collected near Woji-railway and Eliozu dumpsites; (iii) Responses of growth profile of test plants to heavy metals contaminated soils; (iv) Assessment of fluted-pumpkin and waterleaf plants uptake potentials for heavy metals.

3.1 Dumpsite interaction with nearby soils

The Woji-railway and Eliozu dumpsites have strongly interacted with its nearby soil environments. This is evident from the distribution of high level heavy metals in the soil samples collected from short distances away from these dumpsites epicenters as indicated in Day-0 measurements (Table 2), wherein the soils were contaminated with heavy metals such as Cr, Ni, Cd, Zn, Pb and Cu with enrichment factors ranging between 2.42 and 6.04, for which on the scale of measurement, the soils were considered to be moderately to significantly polluted.
This assertion is corroborated by Achadu et al (2018) wherein dumpsites in Benin City and Port Harcourt were found to have actively interacted with their soil and water environments causing large scale pollution.

3.2 Profile of heavy metals content reduction in cultivated soil samples collected near Woji-railway and Eliozu dumpsites.

Soil samples in the experimental pots were subjected to phytoremediation treatments by cultivating in them, fluted-pumpkin and waterleaf plants. As the test plants grew, the different soil samples were routinely taken for heavy metal content analysis on a 10-day interval basis within the 50-day study period. The results obtained showed gradual reduction in heavy metals content of the soils from experimental pots for both Woji-railway and Eliozu dumpsites.

The observed reduction in heavy metals content in soil samples was evident in Table 2; Figures 2 and 3, wherein Cr, Ni, Cd, Zn, Pb and Cu reduced in concentrations starting from Day-0 to Day-50 of the phytoremediation treatment. For instance, at Day-0, Cr concentrations in soils near Woji-railway and Eliozu dumpsites were 26.98 and 24.68 mg/kg respectively, while at Day-50, Cr concentrations reduced respectively to 15.32 and 17.42 mg/kg (Table 2). This observed trend was repeated in all the heavy metals detected in the soil samples for both dumpsites. Figures 2 and 3 also showed objective views of the reduction in heavy metals concentrations in soils from near both dumpsites even as the study period increases from Day-0 to Day-50.

The observed reductions in heavy metals concentrations (due to phytoremediation treatment) in this present study are corroborated by Alabdoudi et al (2018); Khan et al (2019); Shrestha et al (2019) and Hasan et al (2019) wherein soils contaminated with heavy metals also showed decreases in its heavy metals content during phytoremediation treatments with different test plants such as castor cultivars, switch grass and sunflower.

Table 2: Summary of the reduction profile of heavy metals content of soil samples from near Woji-railway and Eliozu dumpsites during phytoremediation treatment.

Heavy metal / Treatment Day	Cr		Ni		Cd		Zn		Pb		Cu	
	Concentration in mg/kg											
	WRD	ELD	WRD	ELD	WRD	ELD	WRD	ELD	WRD	ELD	WRD	ELD
Day-0	26.98	24.68	24.32	24.22	5.21	5.44	70.78	72.18	19.98	21.06	16.98	17
Day-10	25.68	24.02	21.17	24.17	3.31	3.01	65.85	64.56	17.13	17.44	16.89	16.88
Day-20	24.55	22.88	20.86	22.82	2.79	2.78	63.74	62.64	15.48	15.97	16.85	16.87
Day-30	24.02	22.25	20.45	21.42	2.31	2.11	60.4	59.74	13.89	14.55	16.41	16.48
Day-40	23.31	22.25	20.43	20.05	1.67	1.87	50.98	50.45	13.65	13.64	15.89	16.29
Day-50	15.32	17.42	15.35	15.85	1.45	1.48	50.65	48.88	12.75	13.14	12.32	14.22
Background value	10.2	10.2	6.3	6.3	0.9	0.9	21.5	21.5	6.05	6.05	6.5	6.5
Enrichment Factor, EF (at Day-0)	2.65	2.42	3.86	3.84	5.79	6.04	3.29	3.36	3.30	3.48	2.61	2.52
Enrichment Factor, EF (at Day-50)	1.50	1.71	2.44	2.52	1.61	1.64	2.36	2.27	2.11	2.17	1.9	2.19
Percentage Reduction in enrichment, %	43.2	29.4	36.9	34.6	72.2	72.8	28.4	32.3	36.2	37/6	27.4	16.4
Pollution Load Index, PLI (after Day-50)	1.90 (for WRD) 2.06 (for ELD)											

Note: Heavy metal concentration in table = mean of quadruplet; WRD = Woji-railway Dumpsite, ELD = Eliozu Dumpsite

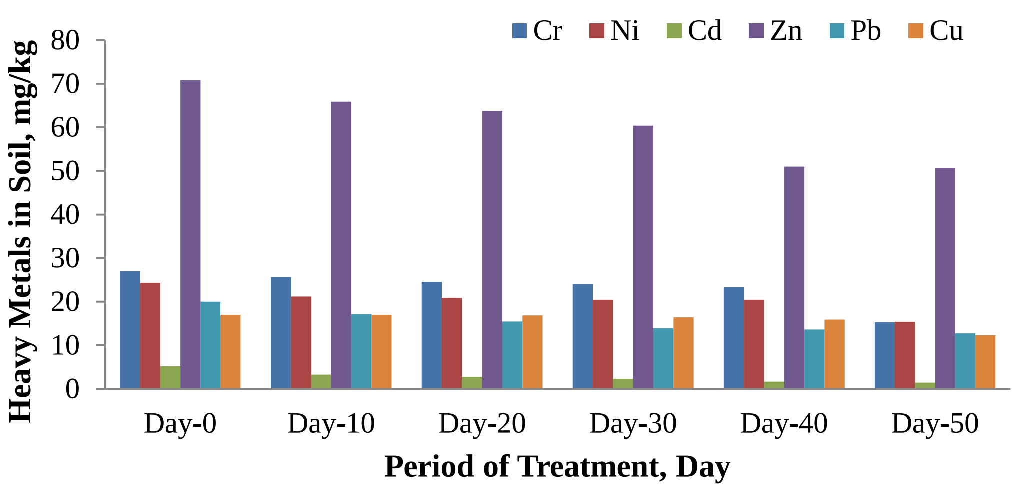

Figure 2: Plots of concentrations of heavy metals in soil versus period of phytoremediation treatment for Woji-railway dumpsite

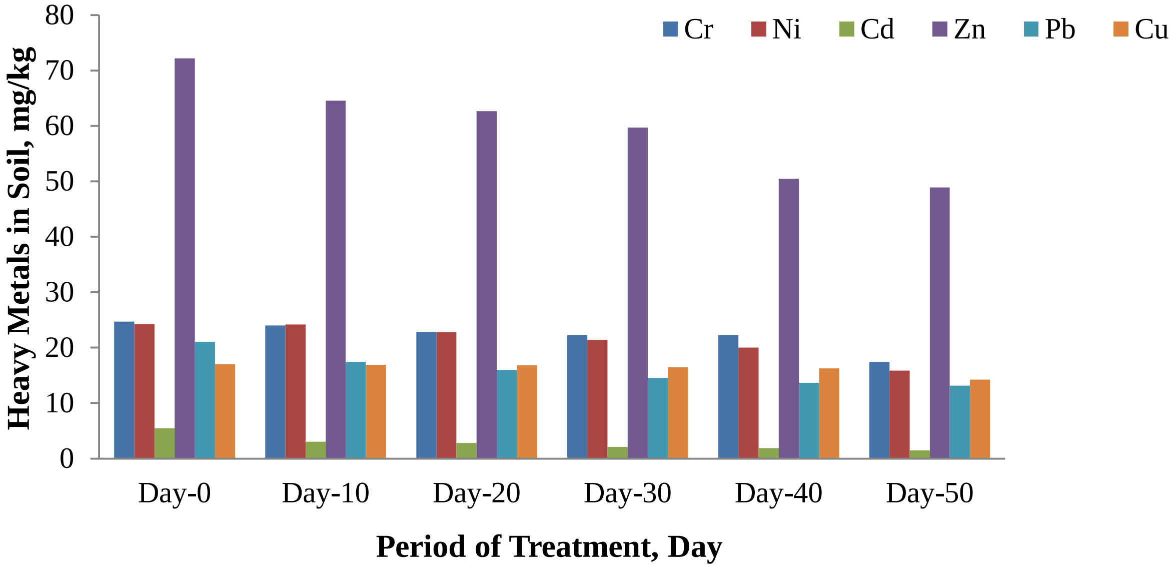

Figure 3: Plots of concentration of heavy metals in soil versus period of phytoremediation treatment for Eliozu dumpsite

3.3 Responses of growth profile of test plants to heavy metals contaminated soils

The growth profiles of cultivated fluted-pumpkin and waterleaf plants in contaminated soils from near Woji-railway and Eliozu dumpsites were observed and monitored within the study period. The growths were generally observed to be gradual and incremental, for which fluted-pumpkin and waterleaf had multiplicity of shoots for which maximum heights were 650 and 25 cm respectively (Table 3). The number of leaves also multiplied incrementally, while the total chlorophyll content (or green coloring matter) of the plants was higher in fluted-pumpkin than in waterleaf (Table 3).

The growth profile for both test plants did not show any physical condition of deficiency or stunting or disease within the study period, hence, there were no significant negative physiological responses of test plants to the soil contaminations with heavy metals. This assertion corroborated Rahman et al (2016) where it was observed that pea's plants showed no significant effect of exposure to heavy metals contaminated soils on its growth characteristics. On the other hand, it was at variant to Goland-goldhirsh (2006), Dasgupta et al (2011) and Tiecher et al (2016) which observed that cultivated chives plant, chick pea and maize plants showed signs of stunting, yellowing of leaves and inhibited seed germination on account of contact with soils contaminated with heavy metals.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 7 Issue 3, March 2020
ISSN (Online) 2348 – 7968 | Impact Factor (2019) – 6.248
www.ijiset.com

Table 3: Measured growth parameters of fluted-pumpkin and waterleaf plant cultivated near dumpsite soils after Day-50.

Test Plant	Leaf Extract	*Shoot Height (cm)	Number of leaves	**Absorbance (au)		Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Total Chlorophyll (mg/g)
				645 nm	663 nm			
Fluted-pumpkin (Telfairia occidentalis)	Harvest from WRD soil	650	58	0.56± 0.001	1.21± 0.002	2.773	1.432	4.205
	Harvest from WRD soil	625	54	0.55± 0.002	0.94± 0.001	2.093	1.639	3.732
Waterleaf (Talinum Fruticosum)	Harvest from ELD soil	25	28	0.45± 0.003	0.87± 0.003	1.969	1.247	3.216
	Harvest from ELD soil	22	22	0.41± 0.003	0.83± 0.002	1.888	1.101	2.989

*Shoot height = mean height of multiple shoots; **Absorbance value = mean of triplicates

3.4 Assessment of fluted-pumpkin and waterleaf plants uptake potentials for heavy metals

Fluted-pumpkin and waterleaf plants were cultivated separately in designated experimental pots containing soils contaminated with heavy metals, collected from near Woji-railway and Eliozu dumpsites. For a period of 50 days, the test plants were nurtured in open air and sunlight, alongside with regular water irrigation. After 50 days of the cultivation, extracts from the plants biomasses were analyzed for heavy metals content. The results showed heavy metals accumulations in the plants leaves, and shoots+roots, being distributed amongst Cr, Ni, Cd, Zn, Pb and Cu in line with the designated experimental pots. On comparing the heavy metals uptake potentials for both plants using bioaccumulation factors (BF), fluted-pumpkin showed slightly higher uptake potentials for heavy metals than waterleaf. This is evident in Table 4, wherein the BF for fluted-pumpkin relative to metal were all slightly higher than that of waterleaf, except for Cd in Woji-railway dumpsite soil where the BF (waterleaf) equals 0.36 and BF(fluted-pumpkin) equals 0.34.

The heavy metals uptake potentials for both plants in this study can be considered to be in the range of low to moderate bioaccumulation. This is because the percentage reduction in heavy metals enrichment was relatively low (< 43 %) for all the metals detected in the soil (Table 2), except for Cd, where the percentage reduction in heavy metal enrichment was 72 %. This has brought the pollution load indices (PLI) for soils collected near both dumpsites to be 1.9 (for Woji-railway dumpsite) and 2.06 (for Eliozu dumpsite) after 50 days of phytoremediation treatment. However, the findings of this present study are at variant to Khan et al (2019), wherein castor cultivars (a wild plant) showed significant uptake potentials for heavy metals in contaminated soils. On the other hand, the study corroborated Muhammad et al (2013) wherein the test wild plant species showed wide variability in macro and trace metals uptake from contaminated soils.

Table 4: **Heavy metals content in plant biomass cultivated on soil samples collected near Woji-railway and Eliozu dumpsites during phytoremediation treatment.**

Test Plant	Cr		Ni		Cd		Zn		Pb		Cu	
	Heavy metals concentration in mg/kg											
Fluted-Pumpkin:	WRD	ELD	WRD	ELD	WRD	ELD	WRD	ELD	WRD	ELD	WRD	ELD
leaves	2.87	2.17	1.89	1.43	0.42	0.34	4.34	5.43	1.39	1.45	0.91	0.67
shoots + roots	3.09	2.29	2.24	3.14	1.37	1.57	7.03	7.85	2.52	2.56	1.45	0.93
Total	5.96	4.46	4.13	4.57	1.79	1.91	11.37	13.28	3.91	4.01	2.36	1.60
*BF	0.22	0.18	0.17	0.19	0.34	0.35	0.16	0.184	0.20	0.19	0.139	0.094
Waterleaf:												
leaves	1.92	1.31	1.86	1.30	0.66	0.41	2.92	2.65	1.14	1.07	0.84	0.47
shoots + roots	3.32	1.37	2.35	2.42	1.21	1.20	5.74	5.34	2.13	2.27	1.41	0.72
Total	5.24	2.68	4.21	3.72	1.87	1.61	8.66	7.99	3.27	3.34	2.25	1.19
*BF	0.194	0.11	0.173	0.15	0.36	0.30	0.122	0.11	0.16	0.16	0.13	0.07

***Bioaccumulation Factor**

4. CONCLUSION

The Woji-railway and Eliozu dumpsites have impacted negatively on the surrounding environments as evident in the heavy metals enrichment of soil samples collected from near the dumpsites. Fluted-pumpkin and waterleaf plants used as test plants for the phytoremediation treatment of the contaminated soils showed adequate uptake potentials and bioaccumulation capacities for heavy metals contained in contaminated soils. Evidences of these assertions are shown in the results obtained as indicated in the increasing percentage reduction in heavy metals content of the cultivated soils within the period of study; the low to moderate bioaccumulation factors for both test plants and the high resistance of test plants in terms of its growth characteristics to the impact of the contaminated soils. The performances of phytoremediation treatments using fluted-pumpkin and waterleaf plants can be further enhanced by amending the contaminated soils with composts. Since the test plants for this study are edible, then, regulatory agencies should further strengthen the prohibition of cultivating edible and grazing plants near open dumpsites. The reason for this recommendation is to prevent heavy metals infiltrations into the ecosystem's normal food chain.

REFERENCES

Achadu, M.A., Uyigue, L. and Obahiagbon, K.O. (2018). Analysis of the Interactions of Dumpsite with Leachate and Groundwater in Benin City and Port Harcourt. International Journal of Engineering and Modern Technology. 4(8): 30 – 39.

Alaboudia, K.A., Ahmeda, B. and Brodiec, G. (2018). Phytoremediation of Pb and Cd contaminated soils by using Sunflower (Helianthus Annuus) plant. Annals of Agricultural Sciences 63: 123–127.

Ali, H., Khan, E. and Sajad, M.A. (2013). Phytoremediation of heavy metals – Concepts and applications. Chemosphere. 91(7): 869-881.

Barbieri, M. (2016). The importance of enrichment factor (EF) and geoaccumulation index (Igeo) to evaluate the soil contamination. Journal of Geology and Geophysics, 5:1, DOI: 10.4172/2381-8719.1000237.

Buekers, J. (2007). Fixation of cadmium, copper, nickel and zinc in soil: kinetics, mechanisms and its effect on metal bioavailability, Ph.D. thesis, Katholieke Universiteit Lueven.

Dasgupta, S., Satvat, P.S. and Mahinrakar, A.B. (2011). Ability of Chick pea (Cicer arientinum L.) for bioremoval of lead and chromium from soil. International Journal of Technology and Engineering System, 2(3): 338-341.

Duffus, J.H. (2002). "Heavy Metals"-A Meaningless Term (IUPAC Technical Report). International Union of Pure and Applied Chemistry, Chemistry and Human Health Division, Clinical Chemistry Section, Commission on Toxicology.
Pure and Applied Chemistry, 74 (5): 793–807.

Duruibe, J.O., Ogwuegbu, M.O.C. and Egwurugwu, J. N. (2007). Heavy metal pollution and human biotoxic effects. International Journal of Physical Sciences, 2 (5): 112-118.

Emsley, J. (2011). The periodic table, nature's building blocks: An A–Z guide to the elements (New ed.). Oxford University Press. 634–651. ISBN 978-0-19-960563-7.

Ghosh, M. and Singh, S.P. (2005). A review on phytoremediation of heavy metals and utilization of it's by products. Asian Journal on Energy and Environment. 6(4):18.

Gogoi, M. and Basumatary, M. (2018). Estimation of the chlorophyll concentration in seven Citrus species of Kokrajhar district, BTAD, Assam, India. Tropical Plant Research, 5(1): 83–87.

Goland-Goldhirsh, A. (2006). Plant tolerance to heavy metals, a risk for food toxicity or a means for food fortification with essential metals: the Allium Schoenoprasum model. Edited: I Twardowska, H.E. Allen and M.M. Haggblom (Amsterdam: Spinger), 479-486.

Guimarães, F.P., Aguiar, R., Karam, D., Oliveira, J.A., Silva, J.A.A. and Santos, C.L. (2011). Macrophytes for removing atrazine from aqueous solution. Planta Daninha, Viçosa-MG, 29:1137-1147.

Gupta, S.K., Herren, T., Wenger, K., Krebs, R. and Hari, T. (2000). In-situ gentle remediation measures for heavy metal-polluted soils, in phytoremediation of contaminated soil and water, Terry, N. and Ba Nuelos, G. Eds: 303–322, Lewis Publishers, Boca Raton, Fla, USA.

Hasan, M.M., Uddin, M.N., Ara-Sharmeen, A., Alharby, H.F., Alzahrani, Y., Hakeem, K.R. and Zhang, L. (2019). Assisting phytoremediation of heavy metals using chemical amendments. Journal of Plants, 8: 295. www.mdpi.com/journal/plants.

Kabata-Pendias, A. and Pendias, H. (2001). Trace metals in soils and plants, Second Edition. CRC Press, Boca Raton, Fla, USA.

Kamble, P.N., Giri, S.P., Mane, R.S. and Tiwana, A. (2015). Estimation of chlorophyll content in young and adult leaves of some selected plants. Universal Journal of Environmental Research and Technology, 5(6): 306−310.

Khan, M.J., Ahmed, N., Hassan, W., Saba, T., Khan, S. and Khan, Q. (2019). Evaluation of phytoremediation potential of castor cultivars for heavy metals from soil. Planta Daninha. 37: e019180998.

Koller, M. and Saleh, H.M. (2018). Introductory chapter: introducing heavy metals. Intech Open. http://dx.doi.org/10.5772/intechopen.74783.

Lasat, M.M. (2000). Phytoextraction of metals from contaminated soil: A review of plant/soil/metal interaction and assessment of pertinent agronomic issues. Journal of Hazardous Substance Research, 2: 1-25.

Liu, D., Jiang, W., Liu, C., Xin, C. and Hou, W. (2000). Uptake and accumulation of lead by roots, hypocotyls and shoots of Indian mustard (Brassica Juncea). Bioresource Technology, 71(3): 273–277.

Muhammad, S., Shah, M.T., Khan, S., Saddique, U., Gul, N., Khan, M.U., Malik, R.N., Farooq, M. and Naz, A. (2013). Wild plant assessment for heavy metal phytoremediation potential along the mafic and ultramafic terrain in Northern Pakistan. Hindawi Publishing Corporation: Biomedical Research International, http://dx.doi.org/10.1155/2013/194765.

Oksana, S., Olena, V., Jamal, R. and Valentyna, F. (2017). The content of photosynthetic pigments in the leaves of galega officinalis l. and galega orientalis lam. Cultivars. Agrobiodiversity Journal for improving nutrition, health and life quality. 2585-8246: 398-403. http://dx.doi.org/10.15414/agrobiodiversity.

Phipps, D.A. (1981). Chemistry and biochemistry of trace metals in biological systems, in effect of heavy metal pollution on plants, N.W. Lepp (Ed.), Applied Science Publishers, Barking.

Pilipović, A., Orlović, S., Nikolić, N., Borišev, M., Krstić, B. and Rončević, S. (2012). Growth and plant physiological parameters as markers for selection of populus clones for crude oil phytoremediation. Croatian Forestry Society (Šumarski list), 136 (5–6): 273–281.

Rabee, A.M., Al-Fatlawy, Y.F., Abdown, A.N. and Nameer, M. (2011). Using pollution load index (PLIi) and geoaccumulation index (I-geo) for the assessment of heavy metals pollution inTigris river sediment in Baghdad region. Journal of Al-Nahrain University, 14 (4):108-114.

Rahman, M.F., Islam, M., Begum, M.C., Kabir, A.H. and Alam, M.F. (2016). Genetic variation in cadmium tolerance is related to transport and antioxidant activities in field peas (Pisum Sativum L.). Archives of Agronomy and Soil Science, 63(4): 578-585.

SERAS (1994). Standard operating procedures for chlorophyll determination. Scientific, Engineering, Response and Analytical Services (SERAS). SOP-2030: 6. https://clu-in.org/download/ert/2030-R00.pdf.

Shrestha, P., Bellitürk, K. and Görres, J.H. (2019). Phytoremediation of heavy metal-contaminated soil by Switch grass: A comparative study utilizing different composts and coir fiber on pollution remediation, plant productivity, and nutrient leaching. International Journal of Environmental Research and Public Health, 16:1261.

Tangahu, B.V., Abdullah, S.R.S,, Basri, H., Idris, M., Anuar, N. and Mukhlisin, M. (2011). A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. Hindawi Publishing Corporation: International Journal of Chemical Engineering, doi:10.1155/2011/939161.

Tiecher, T., Ceretta, C.A., Ferreira, P.A.A., Lourenzi, C.A., Tiecher, T., Girotto, E., Nicoloso, F.T., Soriani, H.H., De Conti, L., Mimmo, T., Cesco, S. and Brunetto, G. (2016). Potentials of Zea mays L. in remediating copper and zinc contaminated soils for grapevine production, Geoderma: Global Journal of Soil Science, 262: 52-61.

USEPA (2007), Treatment technologies for site cleanup: annual status report, 12th Edition. Tech. Rep. EPA-542-R-07-012. Solid waste and emergency response (5203P), Washington, DC, USA.

Uyigue, L. and Enujekwu, F.M. (2017). Physicochemical analysis of gas flaring impact on the environment of host communities in the Niger-Delta. Journal of Environmental Pollution and Human Health. 5 (1): 22 – 29.

Uyigue, L. and Njoku, S.C. (2017). Upgrading the energy management profile of a cement production plant using waste heat recovery and steam boiler system. International Journal of Engineering and Modern Technology. 3(4): 55 – 68.

Usman, K., Al-Ghouti, M.A, and Abu-Dieyeh, M.H. (2018). Phytoremediation: Halophytes as promising heavy metal hyperaccumulators. Open Access Book, Chapter 12. http://dx.doi.org/10.5772/intechopen.73879.