Phytoremediation Potentials of Sunflower (*Helianthus annuus L.*) *Asteraceae* on contaminated soils of Abandoned Dumpsites

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Abstract-Heavy metals are contaminants that poses great environmental burden as they are hazardous to human, animal, plant health and the environment at large. In this Study, the phytoremediation potential of sunflower (*Helianthus annuus L.*) on contaminated soils of abandoned dumpsites was investigated. Some abandoned dumpsites within University of Port Harcourt premises were identified growing with stands of the plant species (*Helianthus annuus*). Samples of both soils and plant were collected and analysed for certain pollutants (Ni, Pb, Cr and Cd) using the Atomic Absorption Spectrophotometer (AAS). Results of analysis were further interpreted using simple descriptive statistical tools. Results of the study confirmed the presence of heavy metals in the soil. Also evidence of accumulation of these metals in the various plant parts studied were established. The leaves of sunflower were found to contain higher concentration (55%) of heavy metals than the stems (45%). From the results, it was clear that cadmium was below detectable level (BDL) in both the soil and the plant parts analysed and lead was found to be lower in concentration compared to nickel and chromium which were higher. Nickel was found to be the most dominant heavy metal (287.6 mg/kg) in the soil samples analysed. Similarly, it was the most accumulated metal (15.71 mg/kg) in the sampled plant parts and clearly exceeds Food and Agricultural Organisation/World Health Organisation (FAO/WHO)recommended threshold limits (1.5 mg/kg) and also those of the control. In all, the concentration of heavy metals in the soil sampled in decreasing order was found to be as follows; Ni > Cr >Pb> Cd respectively where as that of the plant parts includes Ni >Pb> Cr > Cd. Therefore, this study has provided valuable data supporting the use of sunflower plants in phytoremediation.

Index Terms: Cadmium, Chromium, Heavy Metals, Lead, Nickel, Phytoremediation, Sunflower

1 INTRODUCTION

Many clean-up technologies exist for the treatment of contaminated soils, but only few are applicable to heavy metal contaminated soils. The use of plants and associated microorganisms to contain, inactivate, remove or degrade harmful environmental contaminants and to revitalize contaminated sites is gaining more and more attention (Vangronveld *et al*, 2009).

The global problem concerning contamination of the environment as an aftermath of anthropogenic activities is on the increase which has resulted in environmental build-up of waste products of which heavy metals are of particular concern (Yashim *et al*, 2015). This poses significant danger to human, animal and plant health thus, the study aims at providing viable option for clean-up of environmental contamination because phytoremediation is more cost-effective with fewer side effects than physical and chemical techniques (Nasser *et al*, 2013). The observed luxuriant growth of sunflower on abandoned dumpsites in some locations of the study area during reconnaissance visits elicited the interest to further assess the plants potentials in phytoremediation.

The sunflower (*Helianthus annuus L.*) is an annual plant in the family *Asteraceae* has thus been identified as one of the target species that has great potential as a phytoextractor due to the fact that it produces large amounts of biomass, capable of hyper accumulating heavy metals in its harvestable parts (Stems, leaves and roots)and it grows quickly. This study therefore investigated the ability of sunflower plant to phytoremediate soils of abandoned dumpsites contaminated with heavy metals (Ni, Pb, Cd and Cr) by determining the presence of pollutants in impacted soils, determining the presence of pollutants in plant tissues and determining the main plant part of pollutant accumulation.

2 MATERIALS AND METHODS

During reconnaissance survey visits to University of Port Harcourt, some abandoned dumpsites were identified beside the Generator house, in between the commercial banks (Access and UBA Bank Plc) and beside the new CBN building project all situated along the Dan Etete road leading to the main gate of the University. The dumpsites were identified growing with stands of the plant species (*Helianthus annuus*) selected for the study. Similarly, Garmin limited GPS 72H device was used to determine the exact coordinates of the selected sample collection points and were used to show the different sampling site on Google earth map

Table 1: List of Sites used for the study and their respective GPS coordinates.

S/No.	Sampling Site	Longitude	Latitude
1.	Beside Generator House	006^{0}55’ 09.1’’	04^{0}54’ 03.7’’
2.	Beside UBA Bank plc	006^{0}55’ 04.2’’	04^{0}53’ 59.8’’
3.	Beside New CBN Bank Project	006^{0}55’ 02.6’’	04^{0}53’ 57.8’’
4.	Control	006^{0}55’ 05.8’’	04^{0}54’ 03.9’’

Plant Sample Collection

Plant samples of *Helianthus annuus* were collected from each of the sampling sites. The stems and leaves of the sample species were collected using labelled sample bags and taken to the laboratory for determining the presence of pollutants (heavy metals) following the procedure of Uzoukwu (1992). Samples collected 100m away from the dumpsites were used as controls.

Procedure for Plant Digestion

(Dry Ash Method)

The samples were dried in a B and T hot air oven. The dry samples were then crushed using a blender and 20g of the sample was weighed in a Setra electronic weighing balance in a porcelain crucible. The sample together with the crucible was then ashed in a murffle furnace at a temperature of 700^{0}c after which the sample was removed and cooled in a desiccator. It was then dissolved in 20ml of HCL and made up to 1litre with distilled water. Finally the dissolved sample was filtered and the filtrate used for the AAS analysis.

Soil Sample Collection

Soil samples were collected at 0 – 15cm (surface) and 15 – 30cm (subsurface) depth with the help of an Auger from three (3) different points on each of the three (3) sampling sites. Soils collected at each sampling points at 15cm and 30cm were thoroughly mixed and then composited to form one soil sample which was used for replicate analysis. Soil samples were collected and taken to the laboratory using well labelled sampling bags for proper distinction. This was done for all the soil samples collected in the three (3) sampling sites and were analysed for the presence of the pollutants (heavy metals) following the procedure of Uzoukwu (1992). Samples collected 100m away from the dumpsites were used as controls.

Procedure for Soil Digestion

(Hydrochloric Acid Method)

20g of the soil sample was weighed using the Setra electronic weighing balance into a conical flask and 20ml of HCL added. It was heated until it fumes and cooled. The sample was then made up to 1liter by adding distilled water after which it was filtered and the filtrate used for the AAS analysis.

Determination of Heavy Metals using the Atomic Absorption Spectrophotometer (AAS)

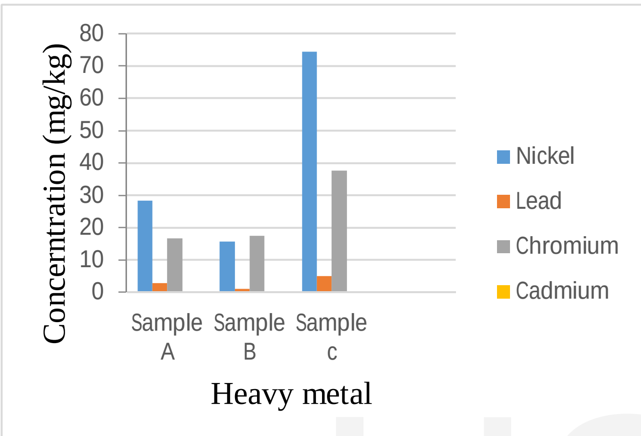
The Atomic Absorption Spectrophotometer (AAS) is a modified spectrophotometer with burner compartment instead of cell compartment. It consists of a radiation source, monochromator, a detector and a measurement system. The AA spectra are formed by the absorption of radiation of certain wavelengths by atoms whose electrons are in a ground state. On absorbing this energy, the atoms become excited. The degree of excitement is dependent on the number of atoms present in the ground state.

Practically a solution of the element digest is sprayed into a relatively cool flame in which the atoms tend to remain in the ground sate. Radiation of a characteristic wavelength from a hallow cathode discharge lamp is passed through the flame and the decrease in intensity is measured using a monochromator and detector system. This decrease is related to the concentration of the element in solution. The AAS machine was used to determine the concentration of Heavy metals in sampled soils and plant tissues.

Procedures for determining Heavy Metals in soil and plant

The machine was first energized and kept for about 15minutes to stabilize. Wavelength recommended for each heavy metal (In this case Ni, Pb, Cr and Cd) absorption was selected. Air and acetylene flow into the burner system was adjusted and regulated. Other essential settings as was recommended in the standard operational procedure were adjusted. The hallow cathode lamp was allowed adequate time to stabilize. Standard solutions for each heavy metal (Ni, Pb, Cr and Cd) were aspirated into the burner system and their equivalent absorbances were obtained. The burner chamber and the aspirator tubing were flushed thoroughly with de-ionized water, then the test sample solution was aspirated and the corresponding absorbance was obtained. The concentration of the metal in the sample was interpolated from the standard heavy metal (Ni, Pb, Cr and Cd) graph plotted by the recording system.

Figure 1: Heavy Metal concentration of soil in site 1



3 RESULTS

The field observation from the various sites investigated showed that the sunflower plant (*Helianthus annuus*) thrived luxuriantly on all the abandoned dumpsites and control sites. The sampling sites were further categorized as follows:

Abandoned Site 1	Beside Generator House
Abandoned Site 2	Beside UBA Bank plc
Abandoned Site 3	Beside New CBN Bank Project
Abandoned Site 4	Control

Analysis of Heavy Metal Concentration

This section presents the results of field sampling and laboratory analysis conducted on the soils and plant samples collected from the identified abandoned dumpsites used for the study.

Heavy Metal Analysis of soil samples

Results from abandoned dumpsite 1 shows that cadmium was below detectable level (BDL) from all the sampled points. Out of the four heavy metals analysed from dumpsite site 1, only three (Ni, Pb and Cr) were detected in the soil samples collected. Samples A and C shows that Ni (28.35mg/kg and 74.45mg/kg respectively) is found in higher concentration compared to sample B where only 15.65mg/kg of Ni was found. The concentration of Cr was 16.65mg/kg, 17.55mg/kg and 37.60mg/kg in samples a, b and c respectively. Also, the concentration of Pb was 2.85 mg/kg, 1.05 mg/kg and 5.00 mg/kg in sampled points a, b and c respectively. Summary of the results are presented (figure1.)

Results of Heavy Metal Parameters of Soils collected from the sampled site 2

The result from abandoned dumpsite 2 clearly shows that cadmium was not detected in the analysis carried out on the soil samples collected. Nickel on the other hand was found to be present in high concentration (57.90, 55.65 and 21.05) mg/kg followed by chromium (31.20, 28.05 and 13.20) mg/kg and lead (2.95, 2.55 and 0.15) mg/kg respectively. Summary of the results are presented in figure2.

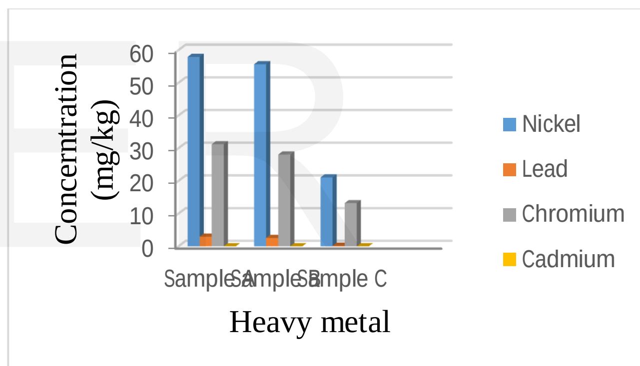


Figure 2: Heavy Metal concentration of soil in site 2

Results of Heavy Metal Parameters of Soils collected from the sampled site 3

The concentration of chromium (16.50 mg/kg, 12.65 mg/kg and 21.30 mg/kg) was found to be higher compared to nickel (7.65 mg/kg, 1.35 mg/kg and 25.50 mg/kg) and lead (4.10 mg/kg, 1.95 mg/kg and 3.05 mg/kg) which were also found in detectable level at the sampled site. The summary of the results are presented figure3.

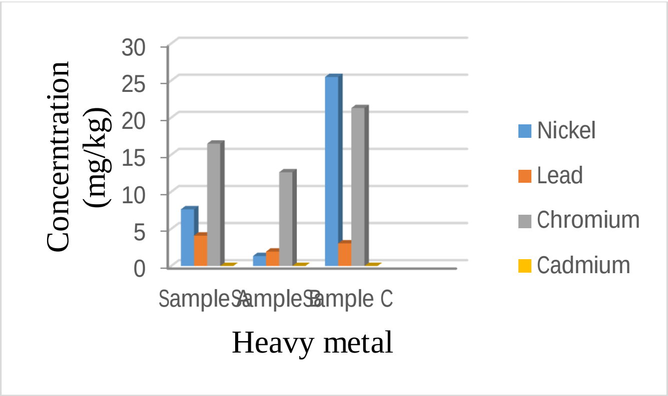


Figure 3: Heavy Metal concentration of soil in site 3

Results of Heavy Metal Parameters of Soils collected from the sampled site 4

Results from the control site depicts that nickel (38.85 mg/kg, 10.35 mg/kg and 28.15 mg/kg) and chromium were (18.05 mg/kg, 22.55 mg/kg and 15.65 mg/kg) found to be more in the soil as represented in figure 4.2.4. Lead (2.70 mg/kg, 2.85 mg/kg and 1.05 mg/kg) was also found in detectable level. Figure 4 presents summary of the results.

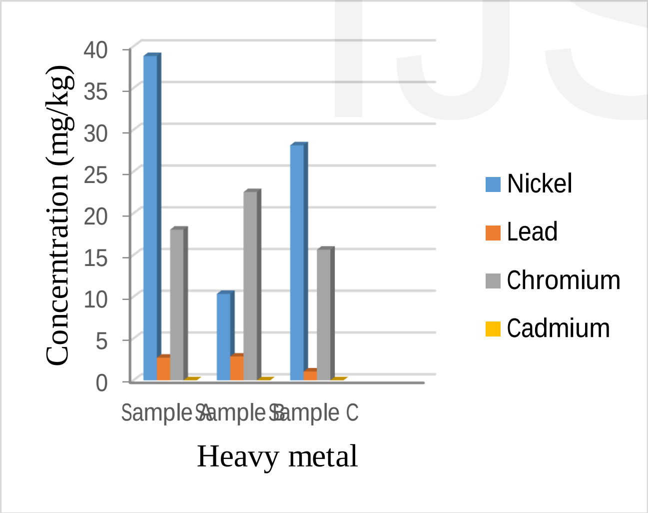


Figure 4: Heavy Metal concentration in site 4 (control)

Heavy Metal Analysis of the plant specimen

This section presents results of laboratory analysis conducted on plant tissue samples of Sunflower collected from the identified abandoned dumpsites. The results shows that cadmium was below detectable level (BDL) in both leaves and stems of the sunflower samples collected. Nickel on the other hand was found to be accumulated more in both leaves and stems samples analysed.

Results from abandoned dumpsite 1 shows the concentration of Sunflower beside the generator house. The metal Nickel (2.40 and 2.98) mg/kg was found to be accumulated in the plant tissues (leaf and stem respectively) analysed followed by Chromium (0.05 and 0.35) mg/kg. Despite the fact that other heavy metals were found in the soil sample collected from the same site, Lead and Cadmium were not found in detectable level in the respective plant parts studied Figure 5 presents summary of the results from site 1

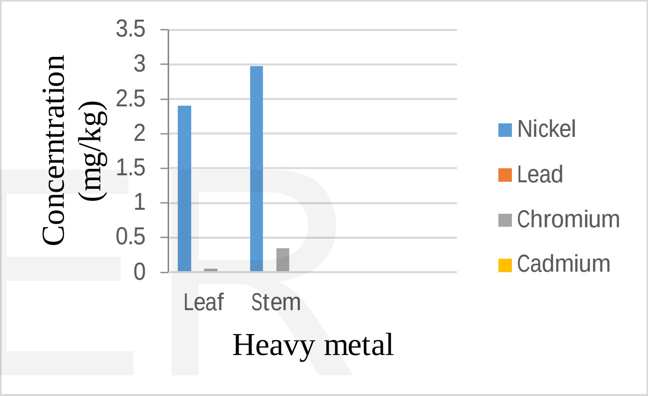


Figure 5: Heavy Metal concentration of Sunflower in site 1

Results of Heavy Metal Parameters of Plant Tissues collected from Site 2

The result illustrated in table and figure6 below shows the level of accumulation of Nickel (2.45 and 1.65) mg/kg in both the leaf and stem respectively. Other metals present in the soil samples collected from the same site were not detected in the plant tissues analysed.

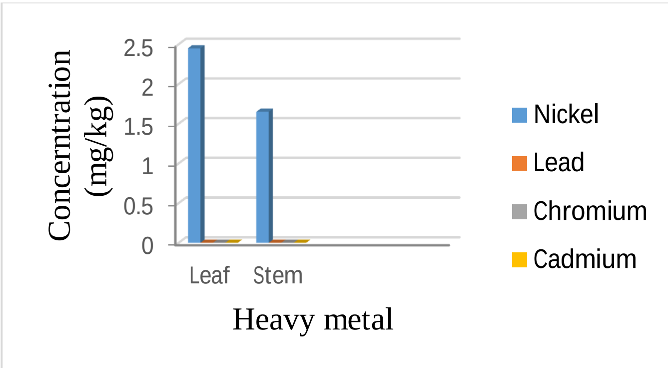


Figure 4.6: Heavy Metal concentration of Sunflower in site 2

Results of Heavy Metal Parameters of Plant Tissues collected from Site 3

Results of laboratory analysis shows that more of nickel was accumulated in both leaf (2.10 mg/kg) and stem (4.13 mg/kg) of the sampled plant parts which is contrary to what was obtainable in the soil sample of the same sampled site. Chromium was also found to be accumulated in leaves (1.80 mg/kg) and stems (0.40 mg/kg) respectively. Summary of these results are presented (figure7.) below.

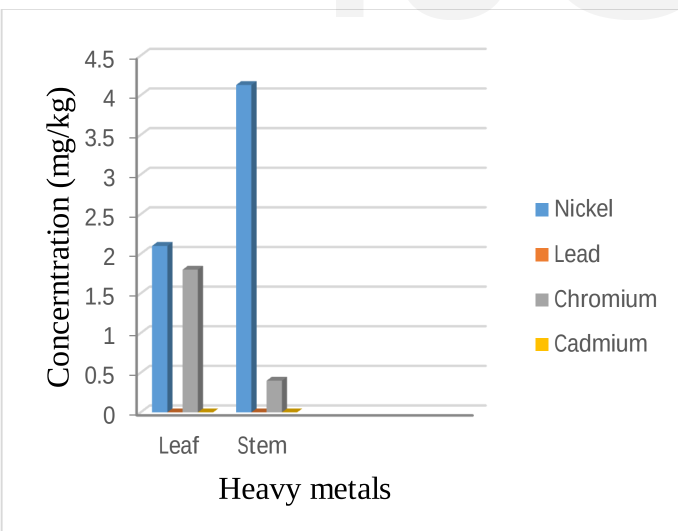


Figure 7: Heavy Metal concentration in Sunflower in site 3

Results of Heavy Metal Parameters of Plant Tissues collected from Site 4

Unlike the control soil samples collected where three of the heavy metals analysed were significantly present, figure 8 shows that there was accumulation of lead (5.95 mg/kg and 3.30 mg/kg) on both plant parts collected and analysed. Chromium was found to be accumulated only on the leaves (0.73 mg/kg).

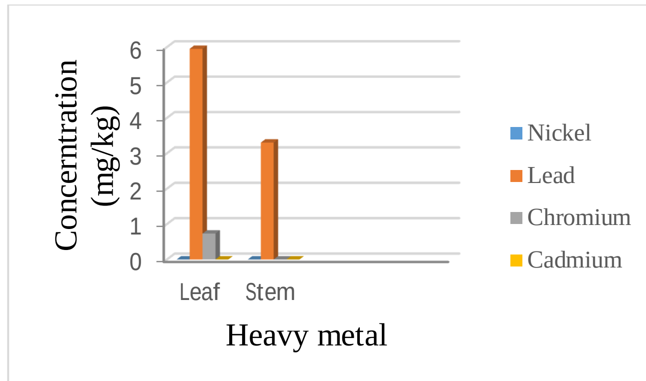


Figure 8: Heavy Metal concentration of Sunflower in site 4 (control)

Percentage compositions of Heavy Metals in plant tissues

Percentage representation in figure 9 shows the concentration of heavy metals in plant parts (leaves and stems) analysed. The pie chart reveals that higher concentration (15.93 mg/kg) of heavy metals were found in the leaves which represents 55% while the least concentration (12.81mg/kg) of heavy metals were recorded in the stems which represents 45%.

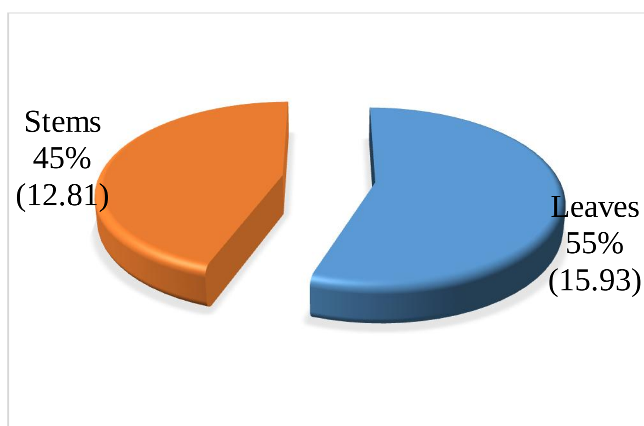


Figure 9: Heavy Metal content in Plant parts

Standard limits of Heavy Metals
Following the Indian standard for plants (table 2.), only nickel (5.38 mg/kg, 4.1 mg/kg and 6.23 mg/kg) was found to be accumulated above the threshold limits (1.5 mg/kg) in all the sampling sites except for the control where it was not detected.

Table 2: Standard limits of heavy metals in Soil/ Plant (mg/kg).

S/No.	Standard	Cd	Cr	Ni	Pb
1.	European Union Standards for soil (mg/kg)	3.0	150	75	300
2.	Indian Standard for plant (mg/kg)	1.5	20.0	1.5	2.5
3.	United Kingdom Standards for soil (mg/kg)	1.4	6.4	-	20
4.	U.S.A Standards for soil (mg/kg)	3.0	400	-	300

Source: WHO/FAO 2007 (Aweng*et al*., 2011) and Abdulmojeed *et al*.,(2011).

4 DISCUSSION

The potentials of sunflower plant to phytoremediate contaminated soils was investigated and result of the studies shows that Cadmium which other studies found to be predominantly present in abandoned dumpsites (Ndukwu *et al*., 2008) was below detectable level (BDL) in all sampling sites.
According to a study conducted by Nasser *et al*., (2013), Cadmium (Cd) has high toxicity to plant functions. Its toxicity is a major factor limiting plant growth. This goes to validate the healthy growth of the sunflower in our sampling sites. Cadmium has severe effects on the chloroplast functions and structures and affects chlorophyll contents. In addition, high concentration of Cd causes oxidative stress which is related to lipid peroxidation of cellular membrane.

The study reveals that lead was found in the sampled soils as well as accumulated in the plant parts analysed. This agrees with the findings of Maclean (1969) who found that ten-fold increase of the content of lead in the soil increases the content of lead in plants only twice. It also agrees with the study done by Ndukwu *et al*., (2008), that found that lead accumulates in abandoned dumpsites over a period. The finding was contrary to the robust growth and flowering of *Helianthus annuus* at the sampling sites. Many studies have shown that lead inhibits metabolic processes such as nitrogen assimilation, photosynthesis, respiration, water uptake, and transcription (Boussama *et al*., 1999). Lead may inactivates various enzymes by binding to their SH-groups and can intensify the processes of reactive oxygen species (ROS) production leading to oxidative stress (Prasad *et al*., 1999). In addition, lead can negatively affect mitochondria structure by decreasing the number of mitochondrial cristae, which in turn can lower the capability of oxidative phosphorylation (Malecka *et al*., 2001).

From this study, results further showed that Nickel was found to be the most dominant heavy metal in the soil samples analysed. Similarly, it was the most accumulated metal in the sampled plant parts hence, it reveals that sunflower has the capacity for bioaccumulating Nickel. This is in contrast to the study by Taiz and Zeiger, (2002) that found that the limited bioavailability of various metallic ions, due to their low solubility in water and strong binding to soil particles, restricts their uptake/accumulation by plants. The plant itself can enhance metal bioavailability. For example, plants can extrude H+ via ATPases which replace cations at soil cation exchange capacity (CEC) sites, making metal cations more bioavailable. Nickel is an essential element for plants and animals.

In thesame vein, Chromium was found in both the soils and various plant tissues sampled. It was the second dominant heavy metal in both soils and plant parts investigated. This concord with the study done by Mahimairaja and Shenbagavalli (2010), they reported that sunflower crop established very well and tolerated a high concentration of soil Cr. This was the case as observed in the sampled site. Obute *et al*., (2001) noted that plants that do well in heavy metal polluted soils may have evolved a means of sequestering these toxic materials in a way as to prevent its toxicity on them. Therefore, these hardy plants (sunflower) may play a role in phytoremediation of heavy metal impacted soils.

The concentration of heavy metals in the sampled plant parts was also determined. It was observed that higher concentration (15.93 mg/kg) of heavy metals were found in the leaves which represents 55% while the least concentration (12.81mg/kg) of heavy metals were recorded in the stems which represents 45%. This agrees with the study by Kumar *et al*., (1995) who opined that plant roots take up contaminants and store them in leaves and stems (harvestable regions). According to Nik *et al*., (2011), leaves accumulates more pollutants than stems and root because they produce large amount of biomass. In all, the concentration of heavy metals in the soil samples in decreasing order is as follow; Ni > Cr >Pb> Cd respectively where as that of the plant parts includes Ni >Pb> Cr > Cd.

5 CONCLUSION

The use of different plant species for cleaning contaminated soils and waters named as phytoremediation has gained increasing awareness since last decade, as an emerging cheaper technology. This research has further validated the fact that phytoremediation is the best way to go coupled with the fact that it is more cost-effective with fewer side effects than physical and chemical techniques.

For this study, it was concluded that biofuel plants like sunflower (*Helianthus annuus*) can remediate contaminated soils and therefore a reasonable choice for remediation of the contaminated sites. Therefore, this study provided valuable data supporting the use of sunflower plants in phytoremediation.

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