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Phytoremediation of soil contaminated with Cr, Cd and Cu by *Gardenia anapetes*.

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Abstract
The phytoremediation of Cu, Cd and Cr in contaminated soil has been investigated. The physico-chemical properties of the soil showed that the metals could be available for plant uptake Selection of plant is an important approach for successful phytoremediation. The suitability of Gardenia anapetes Plant specie for phytoremediation was investigated in a pot experiment with soils from dumpsites and control areas for four months. The shoots and roots of the plants were analyzed for selected metal concentration values before and after phytoremediation. Plant biomass production, bioaccumulation and translocation factors of Cu, Cd, and Cr in G. anapetes were estimated. The biomass production of the plant was of substantial quantity. The bioaccumulation factors of all the metals in all the treatments were < 1. The result also showed translocation factors of Cd and Cr were > 1, and hence the suitability of the plant to be used to sequester these metals from contaminated lands. The plant seems to have higher affinity for Cr.

Keywords: Phytoremediation, *Gardenia anapetes*, translocation factor, dumpsites, bioaccumulation, biomass.

INTRODUCTION

Accumulation of hazardous metals in the ecosystem, especially in soil, through which they can enter into living systems either by the consumption of ground water or may be the food taking by the organism, is becoming a serious global concern (Kamnev and Van der Lelie, 2000). Contamination of the environment by heavy metals is a disaster that originates mainly from anthropogenic activities such as, metal smelting, energy production, mechanized agriculture etc (Urunmatsoma *et al.*, 2010).

These heavy metals when deposited into the soil may change into their most mobile forms thereby contaminating ground water system, plants and other soil microorganisms (Ermakov *et al.*, 2007). Reclamation of toxic metal polluted soils is an issue of great importance. There is no denying the fact that, pollution of our environment with heavy metals is detrimental to our lives (Mojiri *et al.*, 2013). This pollution emanates from man's quest for better life which brought about industrialization and urbanization and then over population (Mojiri *et al.*, 2013).

The soil remediation technology that makes use of indigenous plants to clean up contaminated soils has gain global recognitions recently due to its cost-effectiveness and its environmental friendliness (Zhuang *et al.*, 2007). This technology termed phytoremediation implies the use of indigenous plants and the soil microorganisms to either transform the pollutants into their less harmful forms or to reduce their concentration in the environment (Greipsson, 2011).

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The uptake of these metal pollutants by plants is controlled by many soil properties such as pH, cation exchange capacity, organic matter and plant species. The movement of these metals and their bioavailability in soil are low, in soils with high pH, clay and organic matter contents (Rosselli *et al*., 2003). Other forms of soil treatment include soil dressing and soil washing but due to their high cost of operation and non-environmental friendliness have limited their large scale applications. Therefore, the use of phytoremediation technology for contaminated soil reclamation has received tremendous attention (Elizabeth, 2005).

MATERIALS AND METHODS

Sample soils were collected from dumpsites which are used as amendment in farming vegetables and food stuffs along River Jakara in Kano metropolis Nigeria. The soil was divided into two portions. One portion was air dried, grinded and sieved to pass through 2mm sieve and was used to determine some selected physico-chemical properties of the soil, while the second part was used to test the phytoextraction ability of the selected plant. The plants were first nursed in the soil where they were originally collected for four weeks. After that, the good ones were selected and transplanted in a plastic pot already containing 5 kg of the dumpsite soil or control soil for 120 days.

Plant analysis

After 120 days of planting, the plants were harvested and weighed. The following parameters: Fresh and dry weights, moisture content, total Cr, Cu, and Cd, were estimated before transplanting and after harvesting and the differences reported.

The Plants were washed with de-ionized water to get rid of any surface dust and soil. They were then separated into root and shoot, and then dried at 80^oC until they were completely dried. The dried samples were weighed, and ground to pass through a sieve of 0.50mm mesh size. Exactly 0.50 g of the sieved tissue was digested using concentrated HNO_3 (16.00 M) and $HClO_4$ (12.00 M) at a ratio of 5:1 (v/v). Metal concentrations in the plant sample were afterwards determined using Atomic Absorption Spectrometry (AAS). (Zhuang *et al*., 2007, Mojiri *et al*., 2013).

Translocation of Cr, Cd and Cu from root to shoot was estimated by calculating the translocation factor (TF) for each metal, as:

$TF = C_{shoot}/ C_{root}$

Where C_{shoot} and C_{root} are the amounts of metal in plant shoot and root (mg/kg) respectively (Zhang *et al*., 2002; Fayiga and Ma, 2006).

Bioaccumulation of Cr, Cd and Cu was also calculated as:

$BAF = C_{shoot}/ C_{soil}$

Where C_{shoot} and C_{soil} are metal concentration in plant shoot and in soil (mg/kg), respectively (Ma *et al*., 2001; Cluis, 2004).

Gardenia plant

RESULTS AND DISCUSSION

The values of the selected physico-chemical parameters of the soils differ considerably and are presented in Table 1. The pH values of the waste soils ranged between 6.2 and 7.8. This result is comparable with the works of (Haruna *et al.*, 2011; Dawaki *et al.*, 2015). The acidity (or alkalinity) of a soil defines the availability or otherwise of many nutrients that are required for plant growth (Arias *et al.*, 2005). Thus the measured soil pH values may affect the availability and the subsequent uptake of metals by plants.

The content of soil organic matter varied from 0.68 to 4.05%. These values are also comparable with data from literature (Finzgar *et al.*, 2007; Uba *et al.*, 2008; Obasi *et al.*, 2012). Metals are bound to the surface of organic matter by either complexation, adsorption or through ion exchange thereby restricting their movements and their uptake by plants and microorganisms.

The cation exchange capacity (CEC) of the waste soils range from 3.4 to 13.00 cmol/100g.The higher the soil CEC, the less likely the availability of the soil metals for plant uptake since these metals would have been exchanged with sites on the soil surface thereby becoming trapped (Yoo and James, 2002). It is also reported in literature that, the CEC of soils is dependent on clay and organic carbon contents, more so on organic matter than on the clays (Awode *et al.*, 2008)

All soils with large amount of clay minerals have the potential to concentrate metallic elements (Nessner and Esposito, 2010).

Table1. Some selected physico-chemical properties of the soils

Sample soil		Control soil
pH	6.80	6.60
Organic matter (%)	2.58	1.67
CEC (cmol/100g)	9.90	7.20
Clay (%)	14.06	6.00
Cr (mg/kg)	127.44	4.15
Cd (mg/kg)	31.28	2.11
Cu (mg/kg)	123.24	3.98

Biomass Production

The mean biomass produced by the plants after 120 days is shown in Fig.1. Great differences in biomass were observed between plants in the study samples and those in control soils. The overall production (dry weight) was 39.8g (sample soil) and 37.46g (control) respectively.

Those plants in the sample soil produced higher biomass than their counterparts in the control soils even though; the sample soil had higher levels of the heavy metals. This could be due to the fact that, the sample soils were from dumpsite and therefore may contain more nutrients than the control soils.

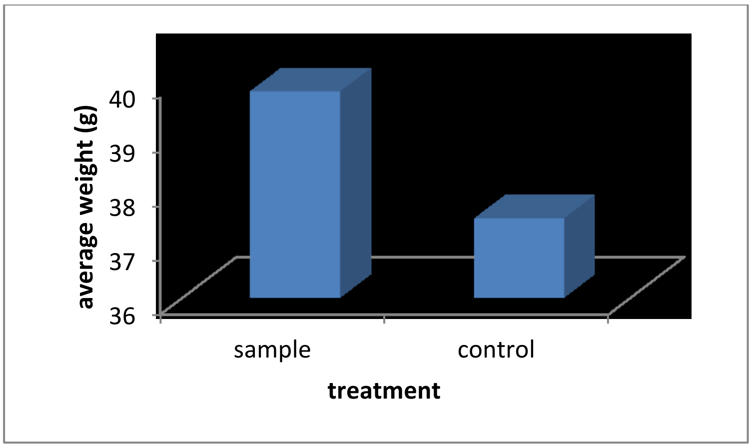

Figure1. Biomass productions (g)

Percentage Reduction in Metal Concentration after Phytoremediation

At the end of the phytoremediation process, there was a general reduction in metal concentrations in all the soil samples. The highest metal reduction in the sample soil was recorded for cadmium (45.30%) and the least for copper (41.12%), while for the control sample the highest and lowest metal reductions were recorded for chromium (66.5%) and cadmium (52.10%) respectively. In general, plants in control soils seemed to have higher percentage metal reduction. This was obvious since metal concentrations in the control soils were much relative to the sample soil and therefore the plants may have been less saturated with the metals hence the higher reduction.

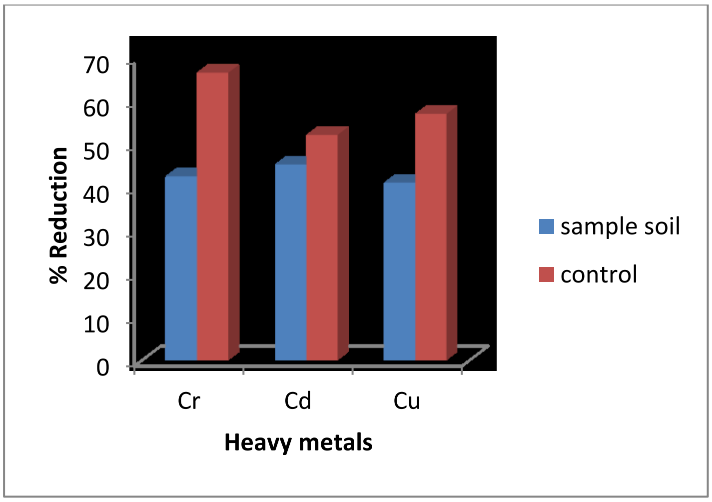

Figure 2 Percentage metal reductions for *Gardenia anapetes*

Average Metal in Shoots and Roots of *Gardenia anapetes*

The average concentration of metals in the shoots and the roots of *Gardenia anapetes* is presented in Table 2. The concentration in both shots and roots varied greatly from metal to metal even the same soil. More of chromium (30.69mg/kg) was contained in the shoot compared to cadmium (7.32mg/kg) for sample soil. Copper had a larger proportion in root (25.74 mg/kg) compared to cadmium (6.85mg/kg). In the control sample, chromium

(1.61mg/kg) and cadmium (0.73mg/kg) were the highest and lowest concentration in shoots while copper (1.48mg/kg) and cadmium (0.38mg/kg) were the highest and lowest concentration in roots respectively. The plant specie seems to have higher affinity for chromium than the remaining metals.

Table 2. Mean metal in shoot and root (mg/kg)

Metal	Sample soil			Control soil		
	Shoot	Root	TF	Shoot	Root	TF
Cd	7.32 ± 4.25	6.85 ± 5.20	1.07	0.73 ± 0.59	0.38 ± 0.23	1.93
Cr	30.69 ± 12.74	23.57 ± 15.89	1.30	1.61 ± 0.89	1.16 ± 0.55	1.39
Cu	23.92 ± 13.06	25.74 ± 7.29	0.97	0.79 ± 0.30	1.48 ± 0.86	0.53

The effectiveness of *Gardenia anapetes* after 120 days of Phytoremediation

There was a general variation in the performance of the plant for each metal. The results from this study showed that *Gardenia anapetes* plant had low metal bioaccumulation factor values (Table 4), indicating that the plant had difficulty in mobilizing the metals in the root zone. It is obvious from this study that soil contaminated with various metals effect the metal uptake by plants. Liu *et al*., (2006) showed that Cd uptake and accumulation in roots and shoots of four maize cultivars varied depending on the different Cd concentrations used and the Cd content in roots and shoots increased significantly. Zhuang *et al*., (2007) also showed that metal bioaccumulation by the plants in multi-metal contaminated soils is low due to the difficulties in metal mobilization by the plants. However, the fact that this plant (*Gardenia anapetes*) able to tolerate and then accumulate significant amount of these heavy metals show its potentialfor phytoremediation. The bioaccumulation factor values in this study are comparable with those obtained in literature (Zhuang *et al*., 2007, Nazir *et al*., 2011).

The suitability of plant for phytoremediation can also be quantitatively determine by calculating the translocation factor (TF) for the metals. The TF indicates the effectiveness of a plant to transfer the metal accumulated in its roots to shoots (Mojiri *et al*., 2012). TF values greater than unity, implies the effectiveness of the plant to transfer the metals from soil to above ground tissue, and hence its suitability to remediate soils contaminated by that metal. Based on Table 3, translocation factors forcadmium and chromium were more than unity in all treatments meaning that, *Gardenia anapetes* plant could be used for Cr and Cd remediation.

Table 3. Bioaccumulation factors

Metals	Sample soil	Control soil
Cd	0.23	0.35
Cu	0.20	0.20
Cr	0.24	0.39

CONCLUSION

Results from this study showed that the heavy metal contents in these sites have been elevated by the dumping of refuse in these areas. The soil parameters determined (such as clay, pH and CEC) revealed that these heavy metals are available for plant uptake. In the effort to ameliorate these pollution sites, the phytoremediation power of *Gardenia anapetes* specie was assessed in this study. The data gathered in the study showed that this plant has the potential to reclaim soils contaminated with cadmium and chromium using proper agronomic practices. This result also shows that the plant tested had difficulty in mobilizing copper into its tissue and hence cannot be used for the metal's remediation.

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