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Accumulation of Lead, Cadmium and Chromium by *Lantana Camara and Nerium* Oleander

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Abstract
The phytoremediation of Pb, Cd and Cr in soil from dumpsites along Jakara River, Kano have been studied. The identification of suitable plant is an important step if phytoremediation process is to be a success. This study evaluated the potentials of two plant species in a pot experiment with soils from dumpsites along Jakara River, Kano. Plant shoots and roots were analyzed for selected metal concentration values. Plant biomass production and translocation factors of Pb, Cd and Cr in Lantana camara and Nerium oleander were investigated. The result showed translocation factors of Pb, and Cr (L. camara) and Cr (N. oleander) to be > 1, and hence these plants could be considered as accumulators of the respective metals. The concentration of Pb in plant shoot ranged from 0.60- 38.09 mg/kg, Cd from 0.45 – 11.41 mg/kg and Cr from 0.89- 39.82 mg/kg. The highest percentage metal reduction was 70 %. The result also indicated that NPK fertilizer application enhanced biomass production considerably.

Keywords: Phytoremediation, *Lantana camara, Nerium oleander*, translocation, accumulators, biomass.

INTRODUCTION
Heavy metal pollution is of great environmental importance because of their deleterious effects on living things as a result of their ability to accumulate in biological systems. The danger they pose to living things is aggravated by their low degradation rate in the environment (Nazir *et al*., 2011). These heavy metals are not easily destroyed through biochemical processes. Cd causes all sorts of harmful effects when accumulated by plants. It disrupts a number of biochemical processes necessary for growth such as oxidative processes and nitrogen metabolism (Attila *et al*., 2001; Laspina *et al*., 2005; Rezvani and Zaefarian, 2011). Man's activities have been the major pathways through which lead reaches the environment since time immemorial. Therefore, lead has bioaccumulated both in different land and water ecosystems (Verma and Dubey, 2003). Chemical washing and dressing techniques have improved soils contaminated by cadmium, however the cost of large uncontaminated soil replacement makes this technique unattractive for large scale application (Rezvani and Zaefarian, 2011).

Toxic metals are not like organic molecules they cannot be degraded but can only be remediated. They therefore require the intervention of mankind for their removal.

Phytoremediation refers to the use of plants in the environment to reduce the concentration or harmful effects of toxic substances in the soil (Greipsson, 2011). It is a new way of reclaiming polluted soil instead of chemical methods. It makes use of green plants to extract, sequester or for the detoxification of the pollutants reducing them to harmless (Isma'il, 2012).

A great number of plants have been investigated with the view of establishing the appropriate plants for different metal decontamination. *Vertiveria zizanioides, Dianthus chinensis, Rumex K-1, Rumex crispus; Viola baoshanensis; Sedum alfredii* (Zhuang *et al*., 2007), *Chromolaena odorata (*Aziz, 2011), *Lapidium sativun (*Mojiri *et al*., 2013), have all been tested.

MATERIALS AND METHODS

Analytical grade purity reagents were used without further purification. Glass wares used were soaked in a 5% nitric acid overnight, washed with detergent, rinsed and oven dried at 110^{o} C before use. Heavy metal content in the soil and plants were determined using AAS (model 280 FSAA).

Nursing and transplanting of plants

Thirty four (34) pots each containing about 5.00 kg of the contaminated soil was used for this research experiment. Eight pots out of the 34, contained soils from control site (labelled as the control). The remaining 26 pots were grouped into 2 groups of 13 samples for the two plants used. Then each of the thirteen (13) groups of samples was subdivided into 2 groups of 6 where one of this group received fertilizer and the other did not. Each of the 6 was further divided into 2 groups of 3 to serve as replicates.

The plants used were first cultivated in the original soil from which they were collected for four weeks. The nursed plants were transplanted one per pot filled with 5.00 kg of the respective soil from either dumpsites or control soils. NPK application was on 4^{th} and 10^{th} weeks after transplanting.

After 120 days of cultivating, the plants were harvested and weighed. The 120 days was chosen so as to allow the plants attain maturity and produce appreciable biomass since biomass production is paramount to the success of the phytoremediation process. The metal concentration of the harvested plants was then estimated.
The harvested plants were washed and then separated into roots and shoots, dried at 80^{o}C until completely dry. The dried samples were weighed, and grounded to pass through 0.50mm sieve. Exactly 0.50 g of the ground samples was digested with concentrated HNO_3 (16.00 M) and $HClO_4$ (12.00 M) at a ratio of 5:1 (v/v) Zhuang *et al*., 2007; Mojiri *et al*., 2013).

RESULTS AND DISCUSSION

Plant biomass production is one of the most important parameters that define the phytoremediation ability of any plant species (Zhao *et al*., 2003; Zhuang *et al*., 2007). The degree to which the metals are extracted rest ultimately on the quantity of plant biomass produced (Lasat, 2000).

The amount of biomass produced by the two plants is given in Figure 1. Both plants produced adequate biomass with total average production (dry weight) of 57.68 g and 73.15 g (non-fertilize and fertilize soils) respectively for *Lantana camara* from sample soil and 37.12 g for control soil. *Nerium oleander* recorded 50.25 g and 64.13 g (non-fertilized and fertilized) sample soils respectively and 43.80 g for control. It was observed that the NPK application enhanced the biomass production of both plants. This may be as a result of the plants receiving more nutrients from the soil with the application of the fertilizer. In turn, those without NPK yielded more biomass than plants from the control soils. This observation however, is in contrast with the findings of Aziz (2011), who reported that *Chromolaena odorata* from the control sample soil yielded more biomass compared to those in soils from the mine dumps and the mine dumps treated with NPK fertilizer.

However, it should be noted that the soil samples from this study come from dumpsites and therefore may contain more nutrients than the control soil, and lower metal load than the tailing soils.

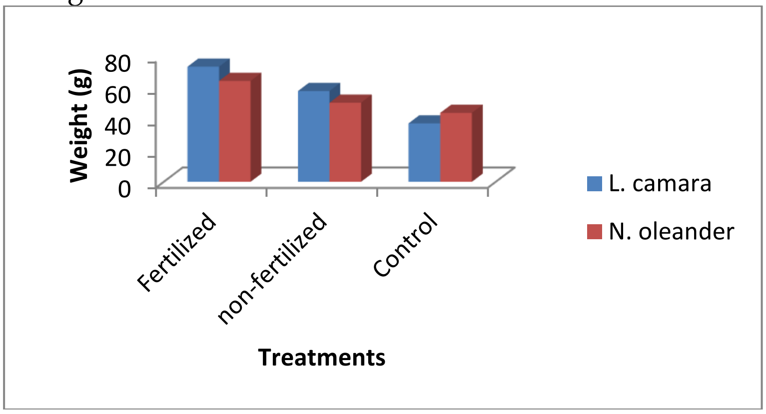


Figure 1. Plant biomass production (g)

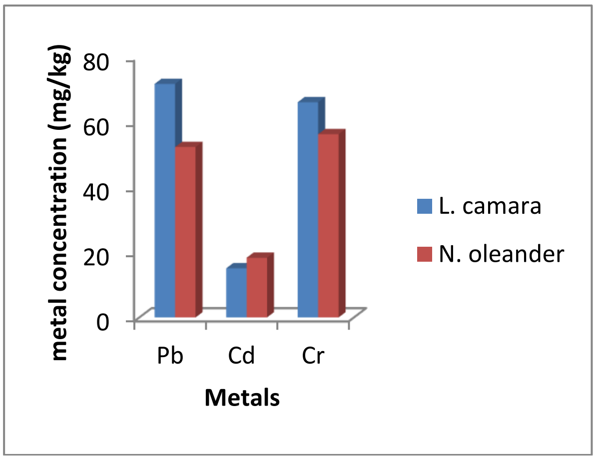
Figures 2a and 2b represent the total amounts of the metals in the plants after phytoremediation. The values were 15.97 mg/kg, 71.70 mg/kg and 66.07 mg/kg respectively in *Lantana camara*; 18.30 mg/kg, 52.30 mg/kg and 56.24 mg/kg, respectively for *Nerium oleander* (non- fertilized). For the fertilized soils, the total metal concentration in plants in the same order were 23.66 mg/kg, 67.93 mg/kg and 62.47 mg/kg respectively for *Lantana camara,* 23.91 mg/kg, 67.17 mg/kg and 70.80 mg/kg for *Nerium oleander*.

There was significant difference (P = 0.008) between the mean cadmium concentration in *L. Camara* fertilized and non- fertilized samples and lead concentration (P = 0.007) for *N. Oleander* fertilized and non-fertilized samples while the other metals showed no significant difference between the two treatments

The cadmium concentration in all the tested plants and in all the soils used ranged between 14.17 mg/kg and 23.91 mg/kg. According to Aziz (2011), plant Cd concentration ranges from 0.05 to 0.2 mg/kg but could be more on contaminated soil. Rezvani and Zaefarian (2011) reported that Cd uptake increases with increase in Cd concentration in the contaminated soil till around 30 mg/kg before it becomes stable in high concentration. In this research, the amount of Cd in plants for the two treatments was higher than this range.

There is normally less lead movement from normal soils into plants (Aziz, 2011). On uncontaminated soils, plants lead accumulation is usually less than 10 mg/kg. The concentration of Pb in all the studied plants was between 52.15 mg/kg and 71.70 mg/kg exceeding the normal levels of Pb in plant. This result agrees with the results of Nazir *et al*., (2011) who obtained lead concentration of 58 mg/kg in *Amaranthus viridis L*. and 91 mg/kg in *Parthenium hysterophorus L*., even though, Rezvani and Zaefarian (2011) showed that high lead concentration reduces shoot weight. Results by Zaefarian *et al*., (2010) also showed that the dry biomass of Alfalfa (*Medicago sativa L*.) reduced, when cultivated on lands contaminated with lead. Again Ardakani *et al*., (2009) noticed poor growth in barley (*Hordem volgare L*) planted on lands contaminated with lead. This means that the tested plants in this study have higher tolerant for lead.

The concentration of chromium in all the plants and in all the treatments was between 54.26 mg/kg and 70.80 mg/kg which is higher than 8.80 mg/kg and 2.10 mg/kg obtained by Urunmatsoma *et al*., (2010) after 20 days of phytoremediation with *Zea mays* grown on chromate copper arsenate contaminated soil amended with cow dung manure.



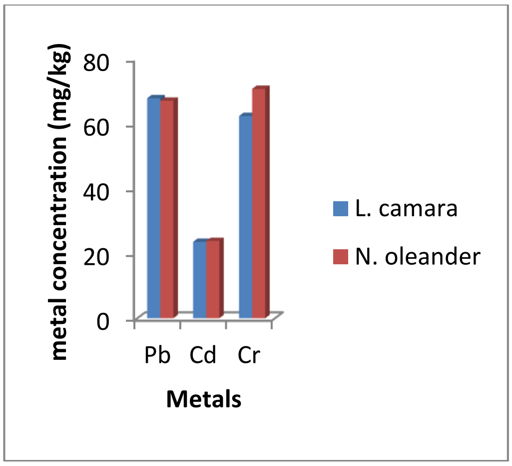


Figure 2a metal concentration in plant without NPK Figure 2b metal concentration in plant with NPK

For all the metals studied using *L. camara*, lead recorded the highest reduction (Table 1) of 53% and 75% respectively for non fertilized and fertilized samples. Overall metal reduction ranged between 48 % and 50 % for non amended and amended soils respectively which is an evidence of the plant potential for the metals.

Table 1. Percentage reduction in metal concentration (*Lantana camara*)

Metals mg/kg	Sample soil	Control soil	Without fertilizer	% reduction	With fertilizer	% reduction	Control	% reduction
Cd	31.28	2.11	15.31	51.05	7.62	75.64	1.24	41.2
Pb	135.25	3.41	63.56	53.00	67.33	50.22	0.53	84.5
Cr	127.44	4.15	61.37	51.84	64.97	49.02	2.40	42.2

For *Nerium oleander*, the metal reduction ranged between 38.6% and 58.5%; and 49.6% to 76.4% for non fertilized and fertilized samples respectively (Table 2). There was an improvement in metal accumulation in plants with amended soils compared to those in non amended soils. This may be due to the increase in biomass, however this improvement did not translate into the translocation powers of the plants.

There was statistically significant difference in percentage metal reduction (P = 0.003) for *L. camara* and *N. oleander* in soils without amendments, while there was no significant difference in percentage reduction for the plants in soils amended with fertilizer (P = 0.567). Significant difference was also observed for *N. oleander* between soil sample, amended soil and the control samples (P = 0.019), while there was no significant difference for *L. camara* (P = 0.901).

Table 2. Percentage reduction in metal concentration (*Nerium oleander*)

Metals mg/kg	Sample soil	Control soil	Without fertilizer	% reduction	With fertilizer	% reduction	Control	% reduction
Cd	31.28	2.11	12.98	58.50	7.37	76.44	1.03	51.2
Pb	135.26	3.41	82.96	38.67	68.09	49.66	1.59	53.0
Cr	127.44	4.15	71.20	44.13	56.64	55.56	1.01	76.7

The average amount of metal in both shoots and roots of *Lantana camara* is presented in Table 3. It appears that the amount of metal in shoots and roots of the different treatment samples vary to a great extent from metal to metal. The root to shoot metal ratio gives a proper insight into the phytoextraction powers of the plants. The lowest concentration in shoot (7.13 mg/kg) as well as roots (8.37 mg/kg), was recorded for cadmium in all treatment soils. For lead and chromium the concentrations in the shoots of *L. camara* were greater than in the roots for the soil sample and sample amended with fertilizer.

Table 3. Mean metal in shoot and root of *Lantana camara* (mg/kg)

Metal	**Sample soil**			**Fertilized sample soil**			**Control soil**		
	Shoot r	Root	TF	Shoot	Root	TF	Shoot	Root	TF
Cd	7.13 ± 3.65	8.37 ± 5.94	0.85	11.41 ± 4.68	12.25 ± 5.91	0.93	0.45 ± 0.28	0.41 ± 0.16	1.10
Pb	38.09 ±11.12	33.61 ±15.84	1.13	36.16 ±10.36	31.76 ±14.93	1.14	1.82 ± 0.46	1.06 ± 0.26	1.72
Cr	37.89 ±21.35	28.18 ±13.26	1.34	35.85 ±19.81	26.62 ±11.96	1.34	0.89 ± 0.27	0.86 ± 0.37	1.03

The total concentration in plant shoots (*N. oleander*) varied from 8.48 mg/kg cadmium to 32.26 mg/kg chromium (non amended); 11.21 mg/kg cadmium to 39.52 mg/kg chromium (amended) and 0.53 mg/kg cadmium to 1.74 mg/kg chromium (control) (Table 4). The highest and lowest concentrations in root for sample soil were 27.64 mg/kg (lead) and 9.82 mg/kg (cadmium) respectively. For the amended soils,. The highest metal concentration in root was recorded for lead (34.42 mg/kg) and the lowest was recorded for cadmium (12.70 mg/kg).

Table 4. Mean metal in shoot and root of *Nerium oleander* (mg/kg)

Metal	Sample soil			Fertilized sample soil			Control soil		
	Shoot	Root	TF	Shoot	Root	TF	Shoot	Root	TF
Cd	8.48 ± 4.36	9.82 ± 4.95	0.86	11.21 ±4.42	12.70 ±5.75	0.88	0.53 ± 0.36	0.55 ± 0.32	0.96
Pb	24.66 ±9.98	27.64 ±8.72	0.89	32.75 ±10.46	34.42 ±9.05	0.95	0.60 ± 0.27	1.21 ± 0.53	0.49
Cr	32.26 ±11.29	23.99 ±13.19	1.34	39.52 ±12.59	31.28 ±13.89	1.26	1.74 ± 0.44	1.40 ± 0.59	1.24

The absorption of metals from soil into roots and the subsequent transfer into the shoots is dependent on element speciation, pH of the soil and some other factors. In the current research, it is clear that plant performance could be hindered if soil being treated is contaminated by several metals. It was demonstrated by Liu *et al*., (2006) that, using four different maize species the amount of Cd absorbed and accumulated in roots and shoots varied with variation in the amount of Cd used. Zhuang *et el*., (2007) also showed that metal bioaccumulation in plants on multi-metal contaminated soil is low due to the difficulty in metal mobilization by the plants.

The success or otherwise of a phytoremediation process can be estimated by computing the ratio of amount of metal in shoot to amount in root called translocation factor (TF). The TF shows the ability of the plant in transferring the absorbed metals from the roots to the shoots (Mojiri *et al*., 2013). The TF factor value greater than 1 shows successful transfer of the absorbed metal from root to the shoot (Zhao *et al*., 2006; Jamil *et al*., 2009). As stated by Nazir *et al*., (2011), plants with TF values more than 1 possess the characteristics of hyperaccumulator plants for that metal. Also Yoon *et al*., (2006), stated that for plants to be considered as potential candidates for phytoextraction purpose, their TF values must be greater than 1.

In this research, the results showed that Pb and Cr were effectively transferred from the roots to the shoots of *L. camara* based on the TF being greater than 1. Also Cr would be effectively translocated in *N. oleander*.

CONCLUSION

Phytoremediation study of heavy metal contaminated soil using *Lantana camara and Nerium oleander* has been conducted. The results of elemental analysis showed that the studied soil is heavily polluted with Pb, Cd and Cr. Statistical analysis on the data obtained showed that at $P \leq 0.05$, significant amounts of cadmium, lead and chromium were removed from the soil by *N. oleander* and *L. camara*. Further statistical analysis on the effect of NPK fertilizer on the overall accumulation of Cd, Pb and Cr in the tested plant was also significant ($P \leq 0.05$).
The results also revealed that, among the two plants tested, *L. camara* accumulated the studied metals better than *N. oleander*.

The findings in this research also indicated that, using appropriate agronomic practices, *L.camara* and *N. oleander* plants could be used to successfully de-contaminate soils polluted with Cd, Pb and Cr.

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