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Plants Level of Chromium and Nickel at a Refuse Site, Any Positive Impact?

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Abstract: Trace metals, including heavy metals can be dangerous to the biota and human beings. Consequently, a study of the accumulation of two unpopular heavy metals, Chromium (Cr) and Nickel (Ni), in four species of plants were carried out. At Ojota refuse sites (Old and New) in Lagos State, Nigeria, from where samples were taken; knowledge about these metals were scarce. The results obtained from the analysis of leaves and roots of plants showed that the sites were heavily polluted by chromium and nickel containing substances, which were indiscriminately dumped at the sites. Values were far above the background level with higher concentrations being recorded at the New Refuse Site (NRS). The concentrations obtained were also found to correlate strongly with the results of some soil physico-chemical properties, which were determined during the study. The plants used in the present research were observed to display a higher level of tolerance to metal concentration, an important characteristic of hyper-accumulator plants in phytoremediation study. Consequently, they are recommended for cultivation in non-grazing heavy metal polluted sites. However, livestock feedings and vegetable consumption at the present sites should be discouraged to avoid metal poisoning.

Key words: Refuse, chromium, nickel, pollution, indicator plants, phytoremediation

INTRODUCTION

The rapid increase in the levels of environmental pollution by heavy metals over recent decades has resulted in an increasing concern for people's well-being and for global ecosystems. There is a long history of association between metals and human development (Tiller, 1989). The concentrations of these metals in soils and consequently in plants at a non-contaminated site are naturally related to several factors such as parent material, mineralogy, biogeochemical cycling, soil age, organic matter, particle size distribution, soil pH, redox concentrations, oxidation states and microbiological activities (Lee *et al*., 1997; Ma *et al*., 1997; Agata and Namiesnik, 2000). Some of these parameters were examined in the present work. Over these natural processes, human activities tend to increase the concentrations of heavy metals such as chromium and nickel and other trace elements in the soils (Dudka, 1992; Dudka *et al*., 1995). Their environmental pathways are of high importance in relation to their toxicity towards flora and fauna.

The present research is concerned with the build up of two heavy metals; Chromium (Cr) and Nickel (Ni) in plants within Olushosun Landfill Site in Ojota, Lagos State, Nigeria. Little attention has been paid to these metals and therefore knowledge is lacking on their deleterious effects. These metals are deposited indirectly and indiscriminately into the site through various products such as stainless steel, alloy products, electrodes, pigment etc. Chromium is toxic in high concentration to both plants and animals. In humans, it can lead to nasal perforation, bronchiogenic carcinomas etc. Nickel has been reported to cause series of lungs problems among many workers (Higgins and Burns, 1975).

Plant analysis gives an indication of the available heavy metal in soil as well as defining the plants own metal load, which is important when the plant is ingested as food. Concentration of chromium and nickel require careful monitoring because potentially dangerous levels may be reached on the plant food diet of animals or humans without any existence of deleterious effect on the plant. Mankovska and Lesnictvi (1997) in their use of plants as bioindicator of heavy metals using a two year old needles of picea abies and leaves of *Fagus sylvatica* in Slovakia obtained concentration (median) in piece abies (*Fagus sylvatica*) as Cr; 0.46 (0.60) and Ni; 2.0 (2.9) mg kg^{-1}.

The sampling site for the present study is the Olushosun Landfill site. This is the largest of the three Landfill sites in the city of Lagos, covering an area of 42 ha of Land. Within the location, there are two sites, the

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old and the new. The waste composition of both sites is as indicated in Table 1 (LAWMA, 1999). Significant releases of volatile compounds were usually observed from these sites due mainly to industrial and municipal waste. Though there are various laws governing control of municipal wastes and industrial pollution, these laws are not being very effective because of the non-cooperative attitude of the local bodies and the industries. At the time of this study, the sites are so mismanaged and financially crippled that nothing good can be expected from it unless some very radical and far-reaching changes are brought about on them. The present study is aimed at creating more awareness to the members of the public about the danger inherent in continuous pollution of our environment.

Table 1: Waste composition in Lagos State

Types of waste	Composition (%)
Vegetables	68
Papers	9
Textiles	4
Metals	3
Plastics	7
Glass	5
Grits	4

Source: LAWMA (1999)

MATERIALS AND METHODS

The Ojota refuse dump site (Old and New) and a control site at Isheri area of Lagos State, Nigeria, were the sampling sites for the present study. Three samples each of four species of plants; *Panicum maximum* (PM); *Eupatorium odorata* (EO); *Carica papaya* (CP) and *Terminalia catappa* (TC) were randomly selected at each location except for *Terminalia catappa* for which only the leaves were sampled. The area map of the sampling location is as indicated in Fig. 1.

To avoid contamination during sample preparation, all glass apparatus and containers were pre-washed thoroughly in distilled water, soaked with HNO_3/H_2SO_4 acid (1:1) mixture, then rinsed with copious amount of de-ionized water.

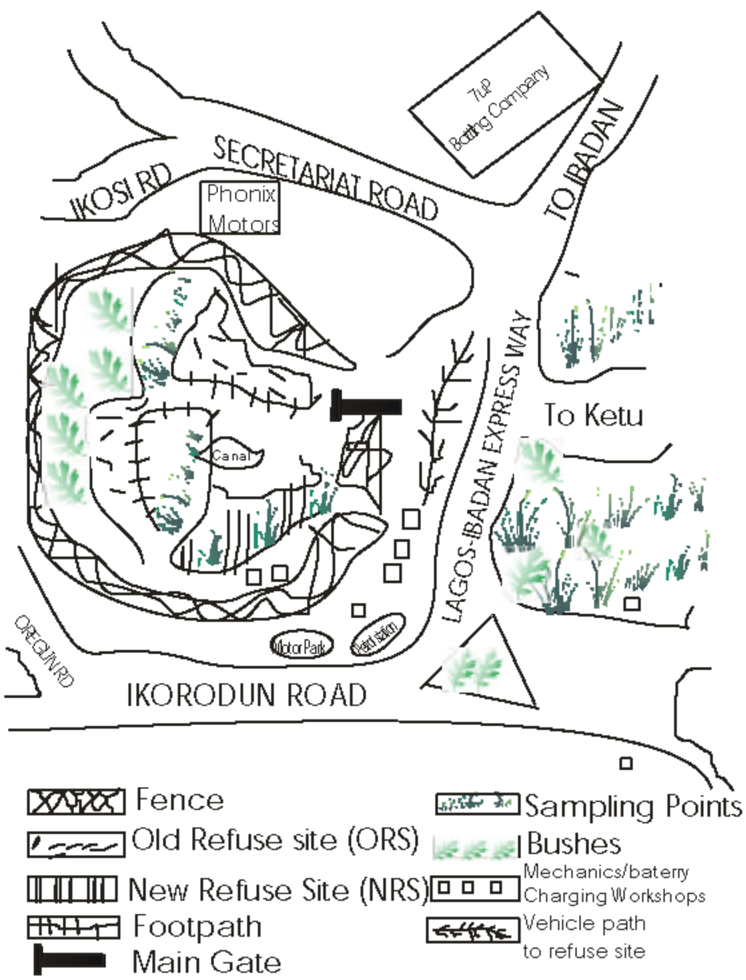

Fig. 1: Schematic diagram of the sampling locations in Lagos State, Nigeria

In the laboratory, the soil samples were dried at ambient temperature (22-25°C), crushed by hand in a porcelain mortar and sieved through a 0.5 mm screen. The standard, dichromate-oxidation was used for the determination of the organic carbon and organic matter content while the pH was determined using the glass-electrode pH meter. Samples were first manually cleaned, then dried in an oven at 95°C for 1 h and ground. Five gram each of the sieved plant samples were weighed into 150 mL beaker, followed by addition of 75 mL modified aqua regia (HNO_3:HCl in 3:1 ratio).

The beakers with the samples were covered with watch glasses and placed on a hot plate. The digestion, performed at a temperature of 90-95°C was continued until the digest was concentrated to 2 mL volume. Then, 30 mL of 30% H_2O_2 were added and the mixture was allowed to evaporate down to a volume of 6 mL after which 10 mL of 2MHCl were added. Further heating was used to reduce the volume to 6 mL. After cooling, the solution was filtered to remove small quantities of waxy (cerous) solids and de-ionized water was added to attain a final volume of 50 mL. The Ni and Cr contents in the plant (leaves and roots) extracts were determined by Atomic Absorption Spectrophotometer (AAS) using a Buck Scientist 200A AAS model. Measurements were made at 232 nm for Ni and 358 nm for Cr.

For the purpose of analysis, blanks were prepared in the same manner as the samples. The values reported are corrected for any metal that might have been contributed by the reagents used during digestion. In order to ascertain the efficiency of the digestion procedure so as to correctly determine the accuracy of the final results, a recovery study was carried out using standard salts of the metals.

RESULTS AND DISCUSSION

The distribution of concentrations of chromium, Cr and nickel, Ni, obtained in plants (leaves and roots) are presented in Fig. 2-5. Table 2 gives the result of some of the physico-chemical parameters examined in this study while Table 3a and b show the results of the statistical analysis. The result showed a wide range of values with the highest concentration of both metals in leaves and roots recorded at the New Refuse Site (NRS). The concentration recorded at the refuse sites (old and new) is a reflection of man's contribution to heavy metal pollution of the environment. All the values fell within the toxic levels at the refuse sites except in the leaves of *Carica papaya* where, though normal, but a threatening value of 4.2 ppm was obtained in its leaves. The geometric means and ranges of chromium and nickel especially at the refuse sites were considered to be of greatest concern to wildlife and ecosystem health.

There are limited local data for the element, Cr and Ni. Average concentrations in the present study were far above most world data. This further exposed our low level of technology, such as recycling and our unfriendly approach towards the conservation of our natural ecosystem.

Table 2: Results of physico-chemical parameters of soil within the old and new refuse site

Locations	Sample*	pH	Organic carbon (%)	Organic matter (%)	Nickel uptake (%)**	Chromium uptake (%)**
Old Refuse	Soil 1	6.94	2.25	3.89	33.8	29.25
Site	Soil 2	8.04	2.04	3.53		
New Refuse	Soil 3	5.15	1.96	3.34		
Site	Soil 4	7.32	2.08	3.00	35.7	40.13

$$**\%\ \text{Metal uptake} = \frac{[M_{Leaves}]}{[M_{Roots}]+[M_{Leaves}]}\times 100\%$$

Where [M] = Concentration of metals. * Soil samples are representatives of each site

METAL VARIATION WITH PLANTS

The leaves-to-roots concentration ratio of metals give the composition of the plant with respect to the percentage metal uptake from the soil. The concentration ratio is element specific and also shows some dependence on the plant species as revealed in the present study. The concentration ratio shows very large variations, both among Ni and Cr in a given sample, as well as among different samples at the refuse sites. Both variations are due to the complex nature of the plant-soil-relationship coupled with the physico-chemical nature of the environment and the high biodiversity of plants (Armin and Leonhard, 1998). In the leaves of the plants studied, a perfectly positive correlation ($p<0.01$) occurs between Ni within ORS and CT and Cr within ORS and CT, respectively. However, it was a perfectly negative correlation between Ni within ORS/NRS and Ni within NRS with Cr within ORS. The correlation data is almost similar within the root zone where the Ni concentration at both NRS and ORS are negatively and perfectly correlated ($p<0.01$). The Cr concentration in the root of all the plants were found to have a strong positive correlation. This shows to a very great extent that Cr bioavailability to plant roots may be independent of the type of plants but probably on some other properties of the soil.

Eupatorium odorata has proved to be relatively most sensitive to Ni in its leaf and root than all the other plants. Chromium has equally been recorded in the highest concentration in the root of this plant. Similar trend were also observed even at the control location.

The plant species employed in the present work can be said to have served as hyperaccumulator in phytoremediation of soil metals. Phytoextraction (the use of plants to remove contaminants from soil) is an aspect of phytoremediation, which serves as very great promise in this work, considering the levels of metals accumulated in the roots of the plants. Considering the physiological state of the plants at the time of sampling, they can be said to have displayed high level of tolerance to the metals in their root and shoot cells as there were no noticeable deformities or malfunction in their parts. Such hyper tolerance is believed to result from vacuolar compartmentalization and chelation (Vogeli-Lange and Wagner, 1990; Ortiz *et al.*, 1995).

What evolutionary advantage does metal hyperaccumulation gives these species? Boyd *et al.* (1994) have demonstrated that high (but not low) nickel levels in leaves of hyperaccumulator can reduce herbivory by chewing insects and reduce the incidence of bacterial and fungal diseases. Generally, apart from *Terminalia catappa*, all the other plants can be said to be useful bioindicator for heavy metals.

Distribution of nickel: The `concentration of nickel in leaves and roots of all the plants examined at the refuse sites (old and new) are very striking. Levels of concern were found and the values are excessively higher than those of chromium of which it shares a common uptake routes (Fig. 2 and 3).

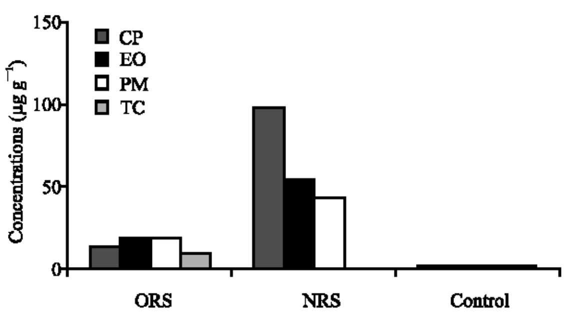

Fig. 2: Distribution of nickel in the leaves of plants

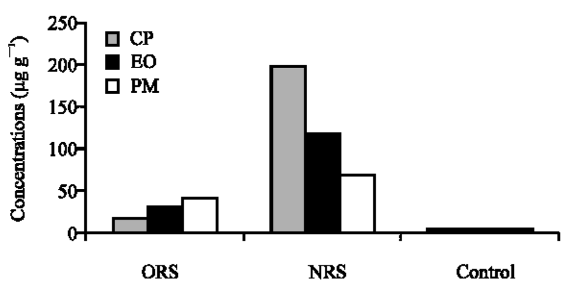

Fig. 3: Distribution of nickel in the roots of plants

In the present work, the concentration of Ni ranges from 1.38-99.1 µg g^{-1} in leaves and 1.90-197. 4 µg g^{-1} in roots with mean values of 23.73 and 53.32 µg g^{-1}, respectively. The concentration was observed to be higher in the roots as expected (Rufus *et al.*, 1997). Out of a total Ni concentration of 730.4 µg g^{-1}, only 250.4 µg g^{-1}, a value corresponding to 34.34% were recorded in leaves. Unlike chromium, the concentration recorded in some of the samples especially by the roots of *Carica papaya* and *Eupatorium odorata* at the NRS exceeded the critical limit (10-100 ppm) of the metal in plants (Holdgate, 1979).

The report above is a strong indication of anthropogenic input by Ni-containing waste materials, which are being dumped indiscriminately into the location. It further shows that pollution of the environment by Ni is at a more significant level that needs urgent attention. However, further investigation would be necessary to determine other reasons for the two elevated levels.

Generally, comparison of plants Ni concentration with results obtained from other studies in other part of the World showed that Ni concentration in the present work is relatively high, though only little could be compared.

Distribution of chromium: The chromium level in the present work ranged from 0.24 to 19.60 µg g^{-1} in leaves and 1.12 to 24.60 µg g^{-1} in roots with mean levels of 6.65 and 25.25 µg g^{-1}, respectively. Like Ni with concentration within the critical limit especially at the refuse site, only about 15.3% of the total plants analyzed especially at the refuse site fell within the normal range in plants. The toxic level recorded at these locations are evidence of anthropogenic inputs, a warning signal and further threat to animal and human health. The distribution among the various plants at each location is as shown in Fig 4 and 5.

The NRS has a higher metal uptake of about 40.13% compared to 29.25% at the ORS. This uptake followed the usual trend of decrease with increasing soil pH, organic

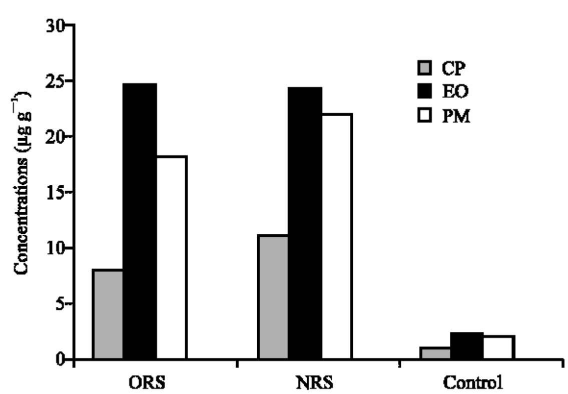

Fig. 4: Distribution of chromium in the leaves of plants

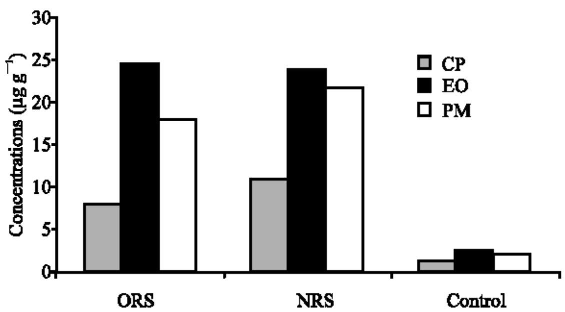

Fig. 5: Distribution of chromium in the roots of plants

Table 3a: Correlations between Cr and Ni contents ($\mu g\ g^{-1}$) in the leaves of studied plants[a]

	Ni (ORS)	Ni (NRS)	Ni (CT)	Cr (ORS)	Cr (NRS)	Cr (CT)
Ni (ORS)	1	-1.000**	0.500	1.000**	0.500	0.500
	-	0.667	-	-	0.667	0.667
Ni (NRS)	-0.994	1	-0.500	-1.000**	-0.500	-0.500
	0.067	-	0.667	0.000	0.667	0.667
Ni (CT)	-0.050	-0.055	1	0.500	-0.500	1.000**
	0.968	0.965	-	0.667	0.667	-
Cr (ORS)	0.947	-0.975	0.274	1	0.500	0.500
	0.209	0.142	0.823	0.000	0.667	0.667
Cr (NRS)	0.912	-0.864	-0.454	0.732	1	-0.500
	0.268	0.336	0.700	0.477	-	0.667
Cr (CT)	0.498	-0.587	0.841	0.751	0.100	1
	0.668	0.601	0.364	0.459	0.936	-

** Correlation is significant at the 0.01 level (2-tailed)

Table 3b: Correlations between Cr and Ni contents ($\mu g\ g^{-1}$) in the roots of studied plants[a]

	Ni (ORS)	Ni (NRS)	Ni (CT)	Cr (ORS)	Cr (NRS)	Cr (CT)
Ni (ORS)	1	-1.000**	0.500	0.500	0.500	0.500
	-	0.000	0.667	0.667	0.667	0.667
Ni (NRS)	-1.000**	1	-0.500	-0.500	-0.500	-0.500
	0.008	-	0.667	0.667	0.667	0.667
Ni (CT)	0.680	-0.689	1	1.000**	1.000**	1.000**
	0.524	0.516	-			
Cr (ORS)	0.695	-0.704	1.000*	1	1.000*	1.000**
	0.511	0.503	0.013	-		
Cr (NRS)	0.848	-0.855	0.965	0.970	1	1.000**
	0.355	0.347	0.168	0.156	-	
Cr (CT)	0.763	-0.771	0.993	0.995	0.989	1
	0.448	0.440	0.076	0.063	0.092	-

** Correlation is significant at the 0.01 level (2-tailed). N = 3 in each case.
* Correlation is significant at the 0.05 level (2-tailed). a Spearman and Pearson coefficients are shown above and below the diagonal line, respectively

matter and organic carbon content of the soil as detailed in Table 3. This is in agreement with the fact that soil of high pH will tend to immobilize larger amounts of heavy metals than soils of a lower pH (Massey, 1972). The high levels of chromium recorded at this location cannot but be associated with the presence of chromium containing waste materials such as stainless steel, textile, tanning leathers and liquid waste such as paint, which are regularly deposited on this location.

Naturally, chromium appears to occur very low. This is evidenced in the result from the control site. It was observed in the present work that out of a total of about 184.4 $\mu g\ g^{-1}$ concentrations recorded in leaves and roots (except those of *Terminalia catappa*) the roots contain 122.6 $\mu g\ g^{-1}$, a value corresponding to 66.5% of the total chromium. This further showed that more of the concentration resides in the root zone. The implication of this is that other edible plants whose roots are often used in soup making, medicinal purposes etc., should be carefully assessed before use.

CONCLUSIONS

The report on chromium and nickel obtained in the present study revealed that pollution of the refuse site through indiscriminate dumping and improper management is already at a level of concern. The use of plant (as indicator) could be considered a starting point for evaluating the degree of pollution as investigated in the present study.

The excessively high concentration recorded above the critical level thus makes the environment very unsafe both for human and livestock survival. Plants at the feeding in order to prevent outbreak of metal poisoning. Consequently, people living around this location (especially drivers, majority of who are illiterates, thus, not environmentally refuse sites (old and New) should be avoided both for household cooking or livestock conscious.) and those who had already inhabited the sites (scavengers) as a means of livelihood should be well informed about the dangers associated with such act.

RECOMMENDATION

It is rather sad to note that despite the strategic location of the refuse site examined in the present work, only little effort has been put in place by the government, which has yielded no significant change. In fact, the situation is becoming worse than at the time of sampling for the present study. Generally, the cost of growing a crop is minimal compared to those of soil and refuse removal and replacement. Hence, the use of plants to remediate polluted soils is seen as having great promise (Cunningham and Ow, 1996; Salt *et al*., 1996). Other plants should be tested other than those employed in the present work to access, in addition to their tolerance to high metal level, their ability to translocate such metal from roots to shoots at high rates (Kramer *et al*., 1996).

Improved hyperaccumulator plants and agronomic technology to improve the annual rate of phytoextraction and to allow recycling of soil toxic metals accumulated in plant biomass is very likely to support commercial environmental remediation which society can afford in contrast with present practices.

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