DETERMINATION OF SELECTED HEAVY METALS IN TOBACCO TREE SHRUBS GROWING AROUND DANDORA DUMPSITE, NAIROBI, KENYA

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Authors' contributions

This work was carried out in collaboration between all the authors. Author PMK designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors JM, JKK and GN reviewed the experimental design and all drafts of the manuscript. All authors read and approved the final manuscript.

ABSTRACT

Environmental pollution by heavy metals is presently a serious threat to public health. Despite the toxic contaminants contained in municipal waste, most of the dumpsites remain unregulated and uncontrolled. The objective of this study was to determine the levels of Pb, Cr and Cd in the leaves of tobacco tree plants growing around the dumpsite so as to assess their impact on the environment. The pseudo-total concentration of the metals in the soil was done so as to calculate the transfer factors.pH and total organic carbon (TOC) of the soil was also determined. Soil and plant samples were collected thrice from sixteen sampling sites along the off-loading path from the centre of Dandora dumpsite up to a distance of 700 m away from the centre at depth of 0-30cm (top soil). Metal analysis was done using flame atomic absorption spectroscopy (FAAS). Pb levels ranged from 7.58±0.34 to 16.57±0.79 µg/g in the washed leaves and 9.22±0.36 to 19.27±0.40 µg/g in the unwashed leaves. Cr levels ranged from 5.11±0.40 to 14.4±0.91 µg/g in the washed leaves and 5.01±0.45 to 15.50±0.40 µg/g in the unwashed leaves. While Cd levels ranged from 0.24±0.01 to 3.62 ±0.17 µg/g in the washed leaves and 0.37±0.02 to 3.68±0.25 µg/g in the unwashed leaves. All these levels were above World Health Organization recommended limits in plants of Pb (0.3 µg/g), Cr (3 µg/g) and Cd (0.2 µg/g). Pearson correlation of the levels in the plants with their concentrations in the soils gave significantly positive values. This suggest that high metal concentration in the soil leads to increased mobility and hence bioavailability. Results obtained therefore suggest that Dandora dumpsite is highly polluted and people should be discouraged from using waste from the dumpsite as manure.

Key words: *Total Organic Carbon, Transfer factors, Dumpsite, Mobility, Bioavailability.*

1. INTRODUCTION

Historically dumpsites have been the oldest and most common forms of waste disposal and remain so in many places around the world. Most of the waste that find its way in dumpsites in most industrial areas includes agricultural wastes, hazardous wastes and wastes from motor garages which contains heavy metals (F.B.G. Tanee and T.N.Eshalomi-Mario, 2015). When in the soil heavy metals circulate by both natural and anthropogenic processes to reach air and plants. Plants accumulate these heavy metals from soils and partly from water and air which later move to animals and especially to man causing adverse health effects (G.Kimani, 2007). One of the sources of heavy metal pollution is from industrial effluent dumped into open sites. Heavy metals take part in biogeochemical cycles and are not permanently fixed in the soil. Therefore, assessment of their distribution in the soil is a key issue in many environmental studies because these heavy metals can find their way in to the food chain causing toxic health effects. The soil acts as a long term sink for heavy metals which have residence times varying from hundreds to thousands of years depending on the element and soil properties (Iyakwari et al., 2016).

Dandora dumpsite attracts special attention in that it is one of Africa's largest dumpsite serving over four million Nairobi residents. Dumping is unrestricted and uncontrolled. Industrial, agricultural and domestic wastes are strewn all over the dumpsite. Nairobi River passes by the dumpsite and heavy metals find their way into the river. Communities living near the dumpsite use contaminated water for irrigation of food crops and in their homes. Waste from the dumpsite is also used as manure by the nearby farmers.

Animals such as pigs, cows and goats feed on plants growing around the dumpsite which leads to the entry of heavy metals into the food chain. Families living near the dumpsite use the site to look for recyclables which they sell for some income. This leads to contact with contaminated soils. A research done by United Nations Environmental Program (UNEP) found most children who were admitted to the nearby hospitals had lead levels exceeding World Health Organization (WHO) limits (G.Kimani, 2007). The pollutants in these wastes include heavy metals such as lead, cadmium and chromium.

Our current study therefore focuses on the determination and comparison of selected heavy metals distribution in various soils and tobacco tree shrubs growing around Dandora dumpsite.

2. Materials and Methods

2.1 Area of study

Dandora dumpsite is located in Nairobi Eastland's 8 km from Nairobi central district. It GPS coordinates are 1.2483^o S, 36.8963^o E. It occupies an area of 121406 sq.m and serves around 4.5 million Nairobi residents since it is the only official dumping location in Nairobi. The main economic activities of the people surrounding the dumpsite arise from the surrounding industries. It receives about 2000 tonnes of waste every day and it is home for many poor individuals who have spent their entire life in the dumpsite (Olayiwola & Azeez, 2017).

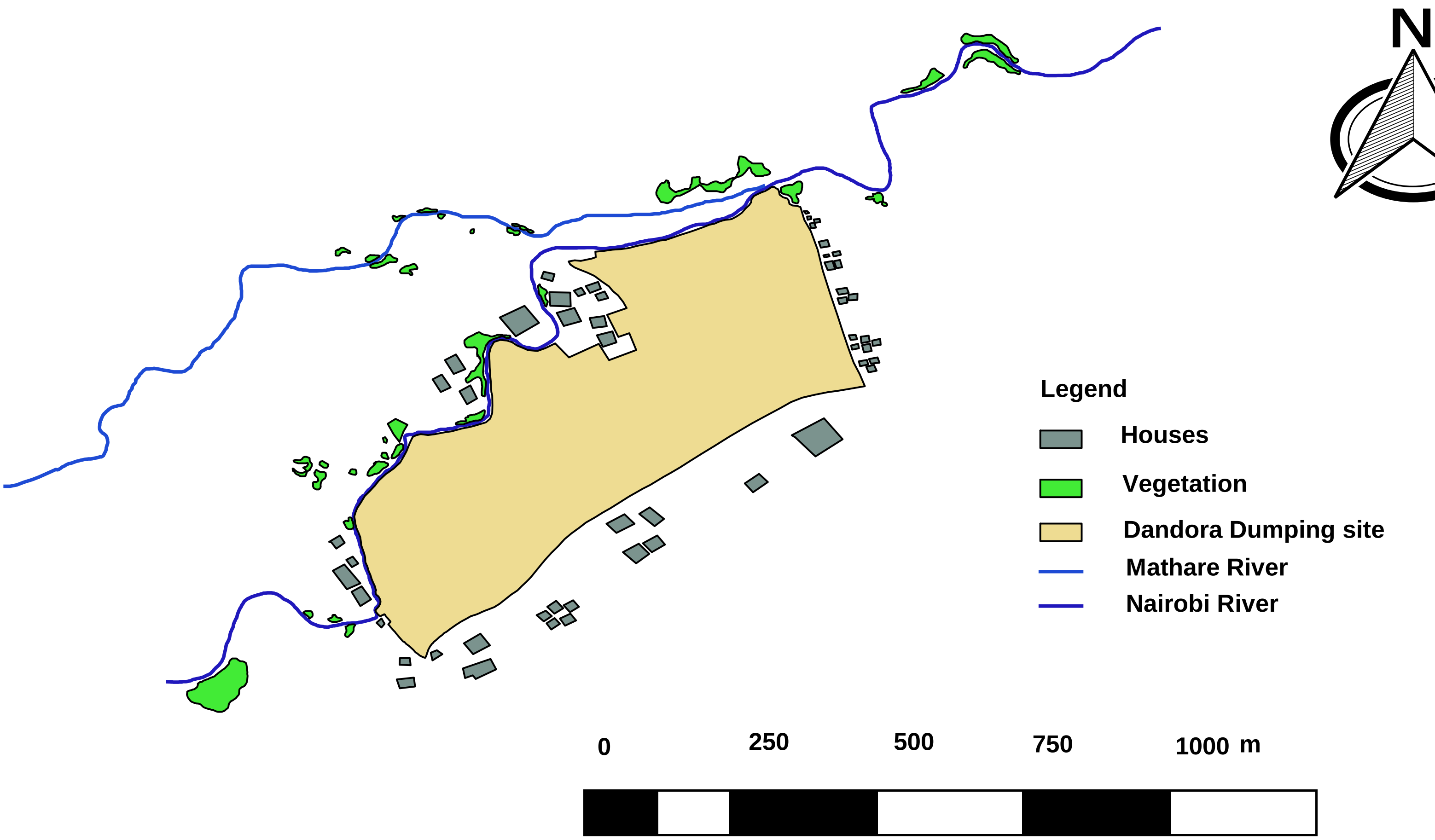

FIGURE 1. Map of Dandora dumping site

2.2 Sampling and Sample Pre-treatment

Sampling was done thrice during the dry months of August, September and October 2018. Soil samples were collected in a stratified way around the dumpsite from a radius of 100 m to 1 km at intervals of 100 m. Soil samples were collected at depths of 0-30cm. A total of 32 soil and 32 tobacco tree plants (*Nicotiana glauca* Graham) samples were collected per sampling period. Plant samples were collected at equidistant points to the soil samples. All the samples were taken to Kenyatta university laboratory for analysis. All soil samples were ground and passed through a 0.1 mm sieve. They were further dried in an oven at 150 ^{0}C for 24 Hours. 1 g of the dried soil sample was placed in a conical flask. To the flask 5 ml of analytical grade mixture of concentrated nitric acid and perchloric acid in the ratio 3:1 were added and the flask placed on a hot digestion block. 10 ml of 0.5 M HCl was added and heated to boiling to recover the metals. The mixture was filtered and diluted to 50 ml in a volumetric flask (Mulamu, 2014). Likewise a blank was also prepared. Soil sample from each horizon in the dumpsite were used to separate metals into four operationally defined fractions through sequential extraction (Esakku et al., 2015).

2.3 Preparation of Plant Samples for AAS Analysis

Plant samples were washed with tap water to remove adhering soil particles and then rinsed with distilled water. Some plant samples were not washed but kept in dust proof polythene bags for analysis of the unwashed leaves. The samples were then cut into small pieces, air-dried for 2 days and finally dried at 100^{o}C in hot air oven for 3 Hours (Olanrewaju, 2019). The samples were then ground and passed through a 1mm sieve. Digestion involved measuring 1g of the ground sample and placing it in a clean flask. To the flask 5ml of analytical grade mixture of concentrated nitric acid, Sulphuric acid and perchloric acid in the ratio 3:1:1 were added and the flask placed on a hot digestion block. 10 ml of 0.5M HCl was added and heated to boiling to recover the metals. The mixture was filtered and diluted to 50ml in a volumetric flask (Mulamu, 2014). A blank comprising of the reagents in the proportions as for the samples but containing no sample material was prepared likewise.

2.4 Determination of Soil pH and Total Organic Carbon

The procedure proposed by (Okalebo et al., 2002) was used in determination of pH and total organic carbon (TOC). Soil sample (8 g) was mixed with 20 mL distilled water, thereafter the mixture was stirred using a glass rod then allowed to stand for 30 minutes with occasional stirring every 10 minutes. After 30 minutes, a pH probe model (Heinritch T205) was placed at a depth of about 3 cm inside the suspension. Readings were taken after about 30 seconds. The pH meter had previously been calibrated using de-ionized water, pH 7.0 and pH 4.0 buffer solutions. Wet oxidation technique which utilizes exothermic heating and oxidation of organic carbon in the sample was used for TOC. 0.3 g of the soil sample was placed in a clean, dry digestion tube and potassium dichromate (5 mL) was added followed by concentrated Sulphuric acid (5 mL). The contents were mixed by swirling. The solution of potassium dichromate was prepared by dissolving 49.024 g of dry salt in about 600 mL distilled water and bringing the volume to 1000 mL with distilled water. The digestion tube with its contents were placed in a digestion block which had been preheated to about 150ºC for 30 minutes. Contents of the tube were transferred into a 200 mL Erlenmeyer flask followed by addition 0.3 mL of indicator. This solution was titrated against 0.2 mol L^{-1} ferrous ammonium sulphate solution. The endpoint of the titration was determined by a change in colour of the indicator diphenylamine.

2.5 Data Analysis

In this study, mean and standard deviation of pseudo-total metal concentrations were determined. One way analysis of variance (ANOVA) ($p \leq 0.05$) were applied to check variations of means between and within sampling stations. Significance of results were tested at the 95 % confidence level. Pearson's product moment correlation analysis was adopted to analyze and establish correlations (r^2) values. The Statistical Package for Social Scientists (SPSS) version 12.0 was used to determine mean concentrations, standard deviations, ANOVA and correlations.

3. Results and Discussion

3.1 Pseudo-Total Metal Content in the Dumpsite Soils

Data presented in table 1 inform of mean± standard deviation, are for the levels of lead, chromium and cadmium in the dumpsite soils at intervals of 100m apart from the centre and a depth of 30cm.

Table 1. Levels of Pb, Cr and Cd in the Dumpsite Soils (µg/g) (n=32)

Metals	Lead	Chromium	Cadmium
1	1087.11±25.64	183.07±14.11	45.52±4.57
2	983.69±50.94	170.52±14.28	30.67±2.68
3	807.59±59.24	139.13±11.49	19.24±3.24
4	318.64±67.02	119.23±9.80	21.74±1.50
5	226.43±20.12	91.36±5.34	23.37±2.21
6	105.04±12.19	69.43±5.46	19.16±1.35
7	71.47±5.14	47.77±2.16	11.84±1.08
8	41.21±4.03	39.16±2.24	10.27±0.44

From table 1 above, metal concentration decreased as the distance from the centre of the dumpsite increased. In all the sites there was a significant difference in levels of the heavy metals with distance. In the upper soil profile the Pb levels in the soils were the highest followed by Cr and the least was Cd. Pb levels in the soils ranged from a mean of 41.21±4.03µg/g in site 8 which is 700m from the centre of the dumpsite to a maximum of 1087.11±25.64 µg/g in site 1 which is at the centre of the dumpsite. The levels of total chromium ranged from 39.16±2.24 µg/g to 183.07±14.11 µg/g over the same range. Cd levels ranged from 10.27±0.44 µg/g to 45.52±4.27 µg/g. These results generally agreed well with ranges of Pb in a Nigerian dumpsite soils report (Sobolev and Begonia, 2008) who reported levels ranging from 1300µg/g to 1693 µg/g. However (Awokunmi, Asaolu, & Ipinmoroti, 2010) found higher levels of lead in dumpsite soil of Nigeria ranging from 3500 µg/g to 6860 µg/g. These high levels of lead in the soil could be attributed to the dumping of used car batteries, used oils dumped from surrounding car garages, expired paints and exhaust fumes from the many lorries which off-load various wastes in the dumpsite. The high levels of Cr could be attributed to dumping of waste from chromate processing industries and peelings from car paints and primers. Wastes from paint industries and asbestos lining erosion could also increase levels of chromium in the soils. Among the three metals under study cadmium had the lowest total concentration. Compared to most soil standards the dumpsite is highly contaminated with cadmium. This could be attributed to dumping of cadmium batteries used in phones, waste from paint industries and metal refining (Katana Chengo, 2013).

3.2 Levels of Pb, Cr and Cd in the Leaves of *Nicotiana glauca* Graham (µg/g)

Determination of heavy metal concentrations in plants was done using flame atomic absorption spectroscopy (FAAS). The mean levels of Pb, Cr and Cd in tobacco tree shrubs growing equidistant to where the soil samples were taken were determined for the washed leaves and unwashed leaves. Results of levels of the three metals in the washed and unwashed leaves are presented in table 2

Table 2. Levels (Mean±SD) of Pb, Cr and Cd in the Leaves of *Nicotiana glauca* Graham (µg/g) (n=32)

	Unwashed leaves			Washed leaves		
Site	Pb	Cr	Cd	Pb	Cr	Cd
1	19.27±0.40	15.50±0.40	3.68±0.25	16.57±0.79	14.40±0.91	3.62±0.17
2	16.15±0.04	15.21±0.40	2.82±0.10	14.29±0.85	12.55±0.57	2.34±0.13
3	13.86±2.01	12.40±0.14	2.10±0.03	13.22±0.49	9.95±0.73	2.05±0.09
4	14.43±0.13	9.34±0.48	1.14±0.31	11.76±0.44	8.91±0.38	1.76±0.05
5	11.07±0.46	5.75±0.23	1.46±0.29	9.54±0.56	7.90±0.71	1.31±0.29
6	11.16±0.40	6.52±0.72	0.61±0.02	9.42±0.62	5.99±0.36	0.54±0.05
7	10.06±0.13	5.30±0.55	0.42±0.01	7.33±0.52	5.74±0.31	0.34±0.01
8	9.22±0.36	5.01±0.45	0.37±0.02	7.58±0.34	5.11±0.40	0.24±0.01

From table 2, metal levels in the washed leaves ranged from7.58±0.34 to16.57±0.79 for Pb, 5.11±0.40 to14.40±0.91 for Cr and 0.24±0.01 to 3.62±0.17 for Cd. In the unwashed leaves metal levels ranged from 9.22±0.36 to 19.27±0.40 for Pb, 5.01±0.45 to 15.50±0.40 for Cr and 0.37±0.02 to 3.68±0.25 for Cd.The unwashed leaves showed higher metal content than the washed leaves , However the differences were not significant at $p<0.05$. It should be noted that animals feed on unwashed leaves hence increasing the possibility of heavy metals into the food chain. In the washed and unwashed leaves the heavy metals exceeded WHO safe limits of Pb (2 µg/g), Cr (1.3 µg/g) and Cd (0.02 µg/g) (Mulamu, 2014). From the table, levels decreased as the distance from the center of the dumpsite increased. This means that animals grazing along or inside the dumpsite can accumulate high levels of Pb. The results are in consistent with those found by (Njagi et al., 2017) where levels of lead in *Solanumvillosum* grown in Kathondeki dumpsite Waithaka Kenya decreased as distance from the dumpsite increased. The amount of metal measured in the soil and tobacco tree plants corresponded with the contamination load of the sampling sites. The differentiation of aerial deposits and uptake from the soil was assessed by washing the leaves. From the results there were substantial aerial deposits of heavy metals although it was it was not statistically significant. Accumulation of heavy metals by plants depends on binding and solubility of particles deposited on the leaves , however, it is difficult to distinguish whether the accumulated elements originate from the soil or from the air through the leaves (Alireza,et al., 2010).Comparisons of heavy metal concentration for both the soil and tobacco tree plant (washed leaves),from tables (1 and 2) indicates lead had the highest levels in both the soil and plant. It was followed by chromium while cadmium was the lowest. For all the three heavy metals the concentration in the washed leaves increased with an increase in the soil heavy metal content. Metal concentrations in both soils and plants decreased as the distance from the centre of dumpsite increased. Many studies have shown that food crops grown in contaminated soils or when watered with contaminated water will accumulate trace metals in their tissues hence living a negative impact on the safety of the food produced(Kr & Bhatt, 2018).Earlier studies on kales have reported high levels on Pb (Njagi et al., 2017). Cd concentration in plant was significantly different in all plants from different sites the highest concentration was in site1 metals concentration increased from Pb, Cr and Cd just like in the soils. The results are in consistent with those found by (Njagi et al., 2017) where levels of lead in *Solanum villosum* grown in Kathondeki dumpsite Waithaka Kenya decreased as distance from the dumpsite increased. A study by *(*Jung, 2008*)*.through a multiple regression using several factors determined that soil metal content was the principal determinant of plant tissue metal content. In cases where metal content in the soil is less than in the plants other metal sources such as dumped items on the spot could be implicated.

3.3 Effects of Physicochemical Characteristics on the Transfer of Metals from Soil to Plants

A good measure of heavy metal uptake by plants is the transfer factor (T.F). This is the ratio of the concentration of the heavy metal in a plant to the concentration of the heavy metal in the soil. It signifies the amount of the heavy metal in the soil that ended up in the plant (Njagi et al., 2017). Transfer factor was calculated in order to understand the risk and associated hazards due to ingestion consequent upon heavy metal accumulation in the edible portion of the plant .The transfer factors (T.F) for each heavy metal were computed based on the method described by (Gandhimathi, 2013). The heavy metal transfer from soil to plants was calculated as follows.

Transfer factor = (Metal content in plant/Metal content in soil) µg/g

Tables 3, 4 and 5 shows effects of pH and TOC on the metal uptake by plants

Table. 3 Effects (Mean±SD) of pH and TOC on Transfer of Lead (n=32)

Site	Soil pH	TOC	Levels in washed leaves (µg/g)	Levels in the soil (µg/g)	Transfer Factor
1	6.21±0.04	15.02 ±0.40	16.57±0.79	1087.11±25.64	0.02
2	5.92±0.13	14.03 ±0.23	14.29±0.85	983.69±50.94	0.02
3	6.50 ±0.36	12.14 ±0.72	13.22±0.49	807.59±59.24	0.02
4	6.50 ±0.04	11.57 ±0.55	11.76±0.44	318.64±67.02	0.04

5	6.94 ±0.40	9.59 ±0.45	9.54±0.56	226.43±20.12	0.05
6	6.55 ±0.36	9.12 ±0.31	9.42±0.62	105.04±12.19	0.06
7	6.54 ±0.34	11.80 ±0.40	7.33±0.52	71.47±5.14	0.11
8	6.01 ±0.13	8.72 ±0.40	7.58±0.34	41.21±4.03	0.11

TOC ranged from 8.72 ±0.40 to 15.02 ±0.40 and it increased with a decrease in distance from the centre of the dumpsite. Transfer factor ranged from 0.02 to 0.11. The results revealed that the higher the soil metal level, the lower the transfer ratio. Bioavailability and toxicity of metals in soils was significantly influenced by pH of the soil. Soil pH is considered to be one of the most important factors that influence transfer of Pb and Cd from soil to plant. pH values ranged from 6.01 ±0.13 to 6.21 ±0.04 suggesting that the dumpsite soils are weakly acidic. It has been shown that solubility of metals increase along with a decrease in soil pH (Fytianos, et al., 2001). Due to low pH in the dumpsite soils the availability of heavy metals to plants was at its highest. From table 3, lead accumulation into the leaves increase with an increase in the organic matter, this was the case for Cr and Cd. Organic compounds can dissolve lightly bound forms of heavy metals resulting in the increase of element uptake by plants (Trevisan et al.,2010). For lead the results agrees with other researchers (Teka et al., 2018). Ironically TOC can also reduce bioavailability of heavy metals in soils by absorption or forming stable complexes with humic substances though this will depend on other factors (Liu,et al., 2009). Similar results of effect of TOC were obtained by (Mbong et al., 2014 and Lasat, 2000).

Table 4. Effect of pH and TOC on Transfer of Chromium (n=32)

Site	Soil pH	TOC	Levels in Washed leaves (µg/g)	Levels in the soil (µg/g)	Transfer Factor
1	6.21±0.04	15.02 ±0.40	14.40±0.91	183.07±14.11	0.03
2	5.92±0.13	14.03 ±0.23	12.55±0.57	170.52±14.28	0.02
3	6.50 ±0.36	12.14 ±0.72	9.95±0.73	139.13±11.49	0.02
4	6.50 ±0.04	11.57 ±0.55	8.91±0.38	119.23±9.80	0.02
5	6.94 ±0.40	9.59 ±0.45	7.90±0.71	91.36±5.34	0.02
6	6.55 ±0.36	9.12 ±0.31	5.99±0.36	69.43±5.46	0.01
7	6.54 ±0.34	11.80 ±0.40	5.74 ±0.31	47.77 ±2.16	0.01
8	6.01 ±0.13	8.72 ±0.40	5.11 ±0.40	39.16 ±2.24	0.01

Chromium levels in the soil were relatively high while its transfer factor ratios was least. This shows that the threat of environmental pollution by chromium is the lowest. This could be attributed to the fact that a high percentage of it is held in the mineral matrix showing that it is largely immobile and less available to plants (Bongoua-devisme et al., 2018).

Table 5. Effect of pH and TOC on Transfer of Cadmium (n=32)

Site	Soil pH	TOC	Levels in Washed leaves (µg/g)	Levels in the soil (µg/g)	Transfer Factor
1	6.21±0.04	15.02 ±0.40	3.62±0.17	45.52±4.57	0.49
2	5.92±0.13	14.03 ±0.23	2.34±0.13	30.67±2.68	0.57
3	6.50 ±0.36	12.14 ±0.72	2.05±0.09	19.24±3.24	0.70

4	6.50 ±0.04	11.57 ±0.55	1.76±0.05	21.74±1.50	0.66
5	6.94 ±0.40	9.59 ±0.45	1.31±0.29	23.37±2.21	0.52
6	6.55 ±0.36	9.12 ±0.31	0.54±0.05	19.16±1.35	0.64
7	6.54 ±0.34	11.80 ±0.40	0.34±0.01	11.84±1.08	0.66
8	6.01 ±0.13	8.72 ±0.40	0.24±0.01	10.27±0.44	0.77

Although cadmium had the lowest levels in the plants, its transfer factor ratios was the highest thus revealing it was the most mobile and bioavailable among the three metals. This shows that it can easily be transferred into the food chain through uptake by plants growing in the soils or any other mechanism Studies have also revealed lower levels of cadmium in spinach grown near motor garages in Nairobi.

3.4 Pearson Correlation Coefficients of Concentration of Metals in the Soils with Concentration in the Washed Plant Leaves

Total concentration of the Pb, Cr and Cd was correlated with the concentration in the leaves of *Nicotiana spp* and the results tabulated in table 6.

Table 6.Pearson Correlation Coefficients of total Pb, Cr and Cd with the Washed Leaves of *Nicotiana glauca* Graham

Metal	Pearson Correlation	P-value
Pb	0.971	<0.001
Cd	0.909	0.002
Cr	0.971	<0.001

There was a strong positive relationship between the amount of metal ions in the soil with metal ions in the plant (P<0.05 Pearson correlation). This showed that an increase in heavy metal concentrations lead to an increase in absorption of metals by plants. It also suggested that the dumpsite soil was the sink for heavy metals leading to their entry into the food chain. These results were in agreement with (Katana Chengo, 2013 and Wyszkowski, 2014).

4. Conclusions

The results obtained from the analysis of Dandora dumpsite soils indicate that the total concentrations of lead, chromium and cadmium were far much higher than typical soil metal contents. The levels of lead chromium and cadmium in the nearby Tobacco tree plants were far much higher than the WHO acceptable limits. Presence of these metals in the plants was an indicator of their mobility and bioavailability. Based from the results obtained from this study, total concentrations of lead, chromium and cadmium in the plants around the dumpsite are high hence the need for control measures and set up of regulations to govern the dumping of municipal waste in the dumpsite. Due to the effects of the dumpsite on the high population living near the dumpsite, it should be relocated into a less populated area. Grazing of animals inside or near the dumpsite as well as farming of vegetables inside or near the dumpsite should be stopped. Use of dumpsite waste as manure by farmers living near the dumpsite should be highly discouraged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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