Heavy Metal Phytoremediation Potential of Wild Plant Species Naturally Growing on Dumpsite, Kenya

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Abstract

Soils form an essential part of life and the main sink of pollutants. Intense industrial and anthropogenic activities have led to serious environmental threats, resulting in increased heavy metal concentration in soils and, consequently, a phytotoxicity effect on plants. Phytoremediation can offer effective and eco-friendly remedies for polluted sites. This study characterized the diversity of various plants that spontaneously grow in a dumpsite and scrutinized their phytoremediation potential. The plants evaluated for phytoremediation potential were *Ricinus communis*, *Parthenium hysterophorus*, *Cassia didymobotrya*, and *Datura stramonium*. The location of the research was Kang'oki dumpsite, Kenya. Species diversity was studied using quadrat sampling thrown randomly throughout the dump site. The bioaccumulation factor (BF) and the translocation factor (TF) were calculated to determine the accumulation and mobility of the heavy metals in the plants. To determine the ability of the plants to remove, accumulate, and mobilize the selected heavy metals, soil and plant sampling was conducted within the 14 sampling sites. The samples were acid-digested, and concentrations of Pb, Zn, Cu, and Cd were analyzed using Atomic Absorption spectrophotometry. Data obtained was subjected to statistical analysis using SAS version 94. Shannon-Weaver diversity index (H') was used for species diversity. An H' of 0.94 and species evenness of 0.45 was found showing a high species diversity on the dumpsite. Cadmium concentration in soil samples ranged from ND to 1.63 mg/kg of soils and 0.4418 to 0.6939 mg/kg of plant tissues. Nickel concentration ranged from 7.9 to 36.33 mg/kg in soils and 9.31 to 11.38 mg/kg in plant tissue, respectively. Copper was found between 3.41 to 121.18 mg/kg of soils and 3.74 to 10.89 mg/kg of plant tissues, respectively. Lead in soils ranged from 13.25 to 8.013 mg/kg of soils and 11.48 to 13.89 of plant tissues. Leaves accumulated significantly ($p < 0.05$) higher amounts of heavy metals than roots and stems. The leaves and stem of *Datura stramonium* showed the highest concentration of cadmium and copper, while its stem showed the maximum concentration of Nickel and lead. *Datura stramonium* showed BCF and TF >1; hence, it can be used for phytoextraction of cadmium. All plants showed TF>1; hence, these plants can be used as hyperaccumulators.

Keywords: Phytoremediation; hyperaccumulators; plant species diversity; bioaccumulation factor; translocation factor

Introduction

Increased human population, industrial development, urbanization, and uncontrolled human activities are primary factors in soil pollution (Oh *et al.,* 2014), resulting in severe consequences such as strains on the ecosystem food chain and significant threats to human and animal health (Oh *et al*., 2014; Paz-Alberto & Sigua, 2013). Additionally, the increased human population results in increased solid waste generated daily, releasing harmful materials where they are deposited (Khalid *et al*., 2017). Soil pollution is one of the leading ecological problems globally (Sipos et al., 2023). Soil pollutants are a major emerging global environmental issue and a concern because they alter the physical, biological, and chemical components of the environment (Oh *et al*., 2014). Leachates and gases released from the wastes pose environmental problems in an ecosystem (Scagila & Adani, 2008). Among the mainly studied contaminants from uncontrolled and untreated wastes are heavy metals such as Zinc (Zn), Arsenic (As), Mercury (Hg), Cadmium (Cd), Nickel (Ni), lead (Pb), and Chromium (Cr).

Heavy metals are toxic elements naturally occurring in environment with atomic density > 4 g/cm^3 and cannot be biodegraded. Heavy metals have biological and non-biological functions on plants' growth and development. They are also ecologically, environmentally, and nutritionally toxic if their level in the ecosystem exceeds the threshold limit (Yashim *et al*., 2014; Obasi *et al.*, 2018). Lead, chromium and cadmium are listed as some of the metals that are toxic even if their concentration in environment is deficient (Dagne *et al*., 2019). For instance, Zinc, iron, molybdenum, and manganese are necessities for efficient plant growth, while mercury, cadmium, and Chromium have functions which have unknown biological functions in plants. However, these heavy metals only harm plants once their concentration exceeds the WHO organization standard for plants and soils (Chibuike & Obiora, 2014). Therefore, phytoremediation is necessary when heavy metals concentration in plants exceeds that in soils.

Various plant species that naturally colonize the contaminated sites have been studied for phytoremediation of polluted sites such as landfills, mining, and quarrying sites. Some plants can thrive and survive in metalliferous soils and have been classified as metal-tolerant plants or bioindicators (Aziz & Mujeeb, 2022). The metal-tolerant plants can decontaminate soils through immobilization, ligand sequestration, exclusion of plasma membrane, and chelation (Yavaş *et al*., 2022); despite some plants' heavy metal tolerance ability to high metal concentration in soils, high concentrations of heavy metals still pose a severe threat to biodiversity (Laghlimi *et al.*, 2015). *Leaching* is a profound environmental impact associated with heavy metals accumulation in the environment. Metal-tolerant plant species spontaneously colonizing polluted soils, such as dumpsite soils, play an important role in preventing leaching of pollutants to the groundwater.

Various approaches have been employed in decontaminating polluted environments, including chemical, physiochemical, or biological techniques. Some techniques also include soil washing, which adversely affects soil's structure and biological components, rendering soil useless (Pulford & Watson, 2003; Danh *et al*., 2009). Some techniques, like conventional treatment, have proved effective in removing organic pollutants from highly polluted waters but ineffective in slightly polluted waters

(Rahman *et al*., 2022). Phytoremediation technology is a promising plant-based bioremediation technology strategized in using plants for decontaminating a non-volatile and immiscible soil content; it is a less expensive and sustainable method (Lee et al., 2021).

Phytoremediation technology is an aesthetically pleasing, solar-driven clean-up method that causes less environmental disruption, is suitable in sites with low-level contamination, is sound in the removal of different types of contaminants from an ecosystem, and is sustainable and inexpensive technology (Mwegoha, 2008). However, the technology has demonstrated limitations, such as the technology tends to be slower than other processes; hyperaccumulators are slow-growing plants. The method is also restricted to sites with low metal concentrations and affected by climatic factors. Mismanagement can lead to food chain contamination, and remediation of a site with multiple metals can be challenging (Laghlimi *et al.*, 2015). This research evaluated selected plants growing spontaneously in Kang'oki dumpsite for phytoremediation potential. However, this study's results provided insight into using naturally growing plants to remediate heavy metal-contaminated sites.

Materials and Methods

Site Characteristics

The study was conducted at Kang'oki dumpsite in Thika Municipality, Kiambu County, Kenya, at 1.0500^{o}S, 37.0833^{o}E (Mwaura *et al*., 2021). The site is characterized by clay and sandy soils. The dumpsite sits at about 40.5 hectares and receives roughly 608.25 tonnes/week of waste (Ephantus *et al.,* 2015). Residential houses surround the dumpsite, several animals graze on it, dogs roaming around, and a large group of waste pickers. Some parts of the dumpsite, which are not active, are covered by bushy vegetation, indicating that the dumpsite has existed for years. The industries that are closest to the dumpsite include several food industries, the British American tobacco industry, and the metal industries.

Plant Species Diversity

Field reconnaissance visits and sampling were conducted during the rainy season between April - July 2018. A Quadrat of 1m x 1 m was used for wild flora that spontaneously grew on the sampling sites. Plants that occurred within each quadrat were counted and recorded. The dumpsite was divided into two parts, representing two sampling blocks, A and B. Block A was further divided into nine sampling sites, representing the most active parts of the dumpsite, and block B was divided into four sampling sites, which comprised the abandoned dumpsite. The sampling sites were labeled sites 1-13. Controlled sites were labeled 14 and 15, representing uncontaminated sites 500 m from the dumpsite area. To identify native plants colonizing the contaminated soil, an inventory of plants growing on Kang'oki dumpsites was conducted. The identification of species was done in accordance with Messou *et al* (2013). With the help of a botanist at Chuka University's botany department, species that were not able to be recognized at the sampling sites were later gathered and identified. During sample collection, photos of the species were captured. Each sampling unit's coordinates were recorded using a handheld GPS device. (Table 1).

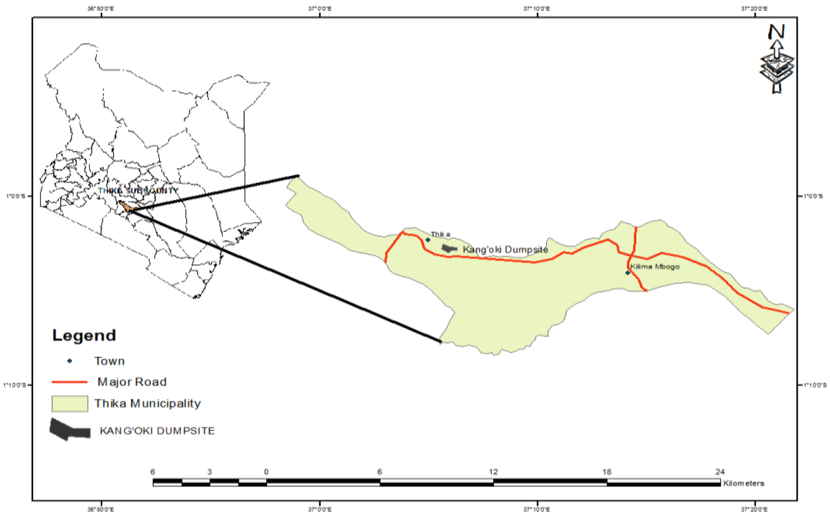

Figure 1: Map of Kang’oki dumpsite, Thika Municipality, Kenya

Table 1: Global positioning system position for each sampling unit

Block	Sampling site	GPS coordinates
	1	S00^{o}19.335’; E037^{o}39.545’; 1383m
	2	S01^{0}04.628; E037^{o}06.604’; 1410m
	3	S01^{o}04.628’; E037^{o}06.620’; 1423m
A	4	S01^{0}04.597’; E037^{o}06.638’; 1455m
	5	S01^{o}04.590; E037^{o}06.660; 1470m
	6	S01^{o}04.625’; E037^{o}06.634’; 1471m
	7	S01^{o}04.612’; E037^{o}06.643’; 1473m
	8	S01^{o}04.591’; E037^{o}06.678’; 1476m
	9	S01^{o}04.612’; E037^{o}06.627’; 1479m
	10	S01^{o}04.625’; E037^{o}06.665’; 1463m
	11	S01^{o}04.656’; E037^{o}06.657’; 1457m
B	12	S00^{o}19.346’; E037^{o}39.554’; 1377m
	13	S01^{o}04.356’; E037^{o}06.614’; 1483

Plants and Soil Sampling

Datura stramonium, *Ricinus communis*, *Cassia didymobotrya* and *Parthenium hysterophorus* were purposively selected for sampling. The four plants species were randomly collected within the 14 sampling sites in three replicates. Soil samples of depth of 0 - 10 cm were collected from the same place where plants were collected. The samples were collected in April 2018 during wet season. The samples were placed in a labeled Khaki envelope and transported to Chuka University chemistry laboratory for further analysis.

At the laboratory, the plant samples were thoroughly washed in running water and rinsed with distilled water to remove soil residue. The plants were separated into leaves, stems and roots. The samples were air-dried for one week then oven dried for three days at 45 ^{0}C. The plant tissues were then homogenized and grounded into powder using pestle and mortar and stored for further analysis. The soil samples obtained from the field were air-dried at room temperature for three weeks. The samples were thoroughly mixed to form composite then sieved through a 2 mm stainless steel mesh to remove non-particulate soils. Samples were then grounded using pestle and mortar and a representative sample obtained through conning and quartering methods.

Data analysis

Plants Species Diversity

Plant species diversity was calculated in accordance with the Shannon-Weaver index (H') (Shannon & Weaver, 1949) as follows

$$H' = -\sum_{i=1}^{n} p_i ln p_i$$

where,

H' is the Shannon-Weaver diversity index

Pi is the proportion of individuals belonging to species i

ln is the natural log, that is, 2.78

To determine the plant species evenness at the dumpsite, Pileou species evenness index was utilized as follows,

$$E = HlogS$$

where,

H is the Shannon-Weaver diversity index

S is the number of species

Plant and Soil Sample Analysis

One gram of the grounded tissue samples was weighed. To each sample, 20 ml of concentrated nitric acid (HNO_3) was added to and then heated on a hot plate until the brown colour ceases. The samples were allowed to cool and 1 ml of concentrated of hydrogen peroxide (H_2O_2) was added and then heated until boiling to clear excess concentrated nitric acid. A 10 ml of ultra-pure water was used to top up the digest to 50 ml, which was then filtered using Whatman filter paper No. 42. Atomic absorption spectrophotometry was used to determine the concentration of heavy metals in the filtrate. The BCF and TF were calculated to determine the accumulation and mobility of Cd, Ni, Cu and Pb. A 2.5 g of representative soil sample was weighed and put into a 100 ml beaker and the samples were made slurry by adding 10 ml ultra-pure water. A 20 ml of aqua regia (nitric acid and sulphuric acid in the ratio 1:3) was added to the slurry sample and then heated in a hot plate until volume was reduced to 20 ml. The samples were allowed to cool and then 4 ml of concentrated hydrogen peroxide was added to the cold sample dropwise and then heated again. The samples were filtered into 50 ml using Whatman filter paper No. 42 and topped up to 50 ml using ultra-pure distilled water. The heavy metals, Pb, Ni, Cd and Cu, were then analysed using AAS.

To determine the accumulation potential of the selected plants, the bioaccumulation factor (BCF) was calculated using the formulae according to Yoon *et al*. (2006),

$$BCF = \frac{The\ ratio\ of\ metal\ concetration\ in\ the\ roots}{The\ ratio\ of\ metal\ concentration\ in\ the\ soil}$$

To determine the mobility of the elements in the soil, translocation factor (TCF) was quantified using the formulae according to Yoon *et al*. (2006),

$$TCF = \frac{The\ ratio\ of\ metal\ concetration\ in\ the\ shoot}{The\ ratio\ of\ metal\ concentration\ in\ the\ root}$$

Statistical Analysis

Data obtained from AAS were subjected to analysis of variance using Statistical Analysis System (SAS) version 94 (SAS Institute, 2013) to determine if the concentration of the selected heavy metals varied significantly from different sites within the dumpsite. The significant means were separated using Least significance Difference (LSD) at α=0.05.

Results and Discussion

Plant Species Diversity

At the Kang'oki dumpsite, 71 plant species representing 28 families were discovered (Table 2). This indicates that there is high species diversity in the dumpsite despite the extreme environmental conditions at the site and domestic and industrial waste flux that come from residential and industries around.

Family Asteraceae was the most abundant with eight species (Figure 1). The families with lowest abundant included Portulaceae, Aizoaceae, Anacardiaceae, Urticaceae, Ulmaceae, Caricaceae, Cyperaceae, Phyllanthaceae, Polygonaceae, Verbenaceae, Molluginaceae, Cactaceae and Nyctagynaceae, which were all represented by single species Fig 2). *Parthenium hysterophorus*, a species in the Asteraceae family, was the most prevalent among the species in both the control site and all sampling sites. At the Kang'oki dumpsite, *Ricinus communis*, *Datura stramoniun*, *Amaranthus spinosus*, and Cynodon dactylon, also known as Bermuda grass. Species such as Carica papaya, *Opuntia violacea*, and *Pisum sativum* were also common at the dumpsite. A species inventory was also conducted in the control site, and the findings indicated that certain *Parthenium hysterophorus*, *Cassia didymobotrya*, *Lantana camara*, and *Cynodon dactylon* were common in both the dumpsite and the control site. Of all the vegetation encountered at the dumpsite, herbaceous plants was the most dominated, it accounted for 57.7% which is similar to previous studies by Dwyer *et al.* (2000) ;Wu *et al*. (2021). other vegetation encountered at the dumpsited were; 5.1% were trees, 11.5% forb, 5.1% climbers, 7.7% grass, and 12.8% shrubs (Figure 2) Most of the herbaceous plants present at the dumpsite were perennial weeds However, majority of the plant taxa were specific to the dumpsite and were commonly distributed both in the abandoned and recently active sites. When considering each site separately, species diversity was found to range from 0.1 to 0.36 (Table 3); diversity also increased across in altitude. The number of species, as shown in Table 3, varies across the dumpsite. According to Pyšek *et al*. (2003), species richness and diversity are negatively impacted by altitude. Research indicates that the number of plant species present in a landfill site is directly related to the level of toxicity.

Table 2: Plant Species Naturally Growing at Kang'oki Dumpsite

Family	Species	Habit
Acanthaceae	*Crabbea volutina, Adhatoda vasica and Asystasia mysorensis*	Herb
Aizoaceae	*Triunthema portulacastrum*	Herb
Anacardiaceae	*Mangifera indica*	Tree
Amaranthaceae	*Achyranthes aspera L., Amaranthus spinosus*, *Amaranthus hybridus* and *Amaranthus viridis*	Herb/forb
Apocynaceae	*Calotropis procera* and *Carissa edulis*	Shrub/tree
Asteraceae	*Ambrosia artemisiifolia*, *Parthenium hysterophorus*, *Xanthium strumarium*, *Bidens pilosa*, *Launea cornuta*, *Lactuca virosa*, *Tagetes minuta L.* and *Schkurhia pinnata*	Herb/forb
Cactaceae	*Opuntia violacea*	Shrub
Caricaceae	*Carica papaya*	Herb
Ceasalpiniaceae	*Cassia didymobotrya* and *Cassia accidentalis* and *Cassia tora*	Shrub/herb
Commelinaceae	*Commelina Africana* and *Commelina banghalensis*	Herb
Convolvulaceae	*Ipomoea batatas*, *Ipomoea carnea Ipomoea purpurea* and *Grandpa Ott*	Herb/Scrambler
Cucurbitaceae	*Citrullus lanatus*, *Cucurbita moschata* and *Cucurbita pepo*	Climber/herb
Cleomaceae	*Cleome gynandra* and *Cleome hassleriana*	Herb/forb
Cyperaceae	*Cyperus rotundus*	Sedge
Euphorbiaceae	*Ricinus communis* and *Acalypha indica*	Shrub/herb
Fabaceae	*Phaseolus vulgaris*, *Vigna rudiata*, *Vigna unguiculata*, *Pisum sativum*, *Leucaena leucocephala and Acacia spp*	Herb/tree
Lamiaceae	*Leonotis nepetifolia, Nepeta hindostana* and *Plectranthus fruticosa*	Herb/shrub
Malvaceae	*Sida acuta*, *Sida rhombifolia*, *Urena lobate*, *Triumfetta rhomboidea*, *Corchorus olitorius*, *Abutilon indicum* and *Malvastrum coromandelianum*	Forb/herb/shrub
Molluginanacea	*Mollugo nudicaulis*	Herb
Nyctagynaceae	*Boerhavia erecta*	Herb
Poaceae	*Cynodon dactylon*, *Cynodon dactylon (Bermuda grass), Zea mays*, *Setaria glauca*, *Setaria viridis* and *Digitaria sanguinalis*	Grass
Polygonaceae	*Oxygonum sinuatum*	Herb
Portulaceae	*Portulaca oleracea*	Forb/herb
Phyllanthaceae	*Phyllanthus niruri*	Herb
Solanaceae	*Datura stramonium*, *Lycopersicon escalentum, Solanum lycopersicon* and *Solanum surratense*	Herb
Ulmaceae	*Holoptela integrifolia*	Tree
Urticaceae	*Urtica massaica*	Herb

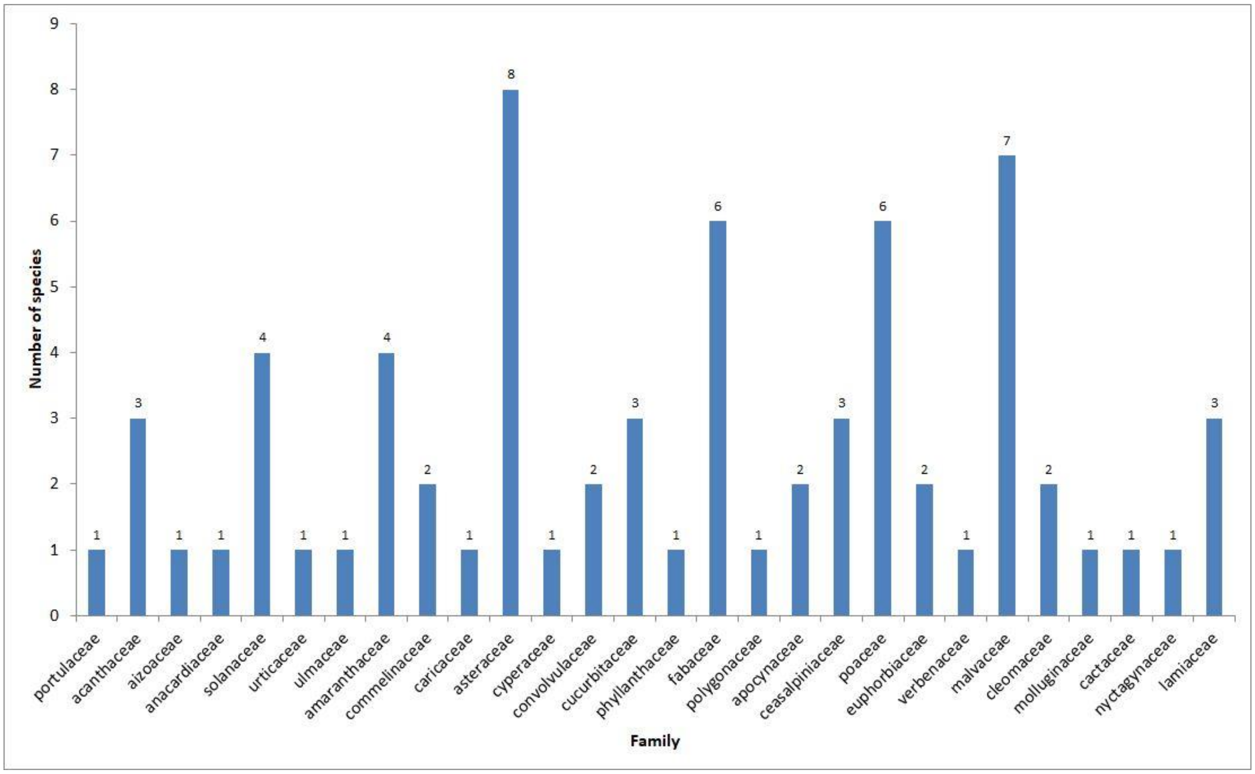

Figure 2: Family distribution of plant species inventoried at kang'oki dumpsite

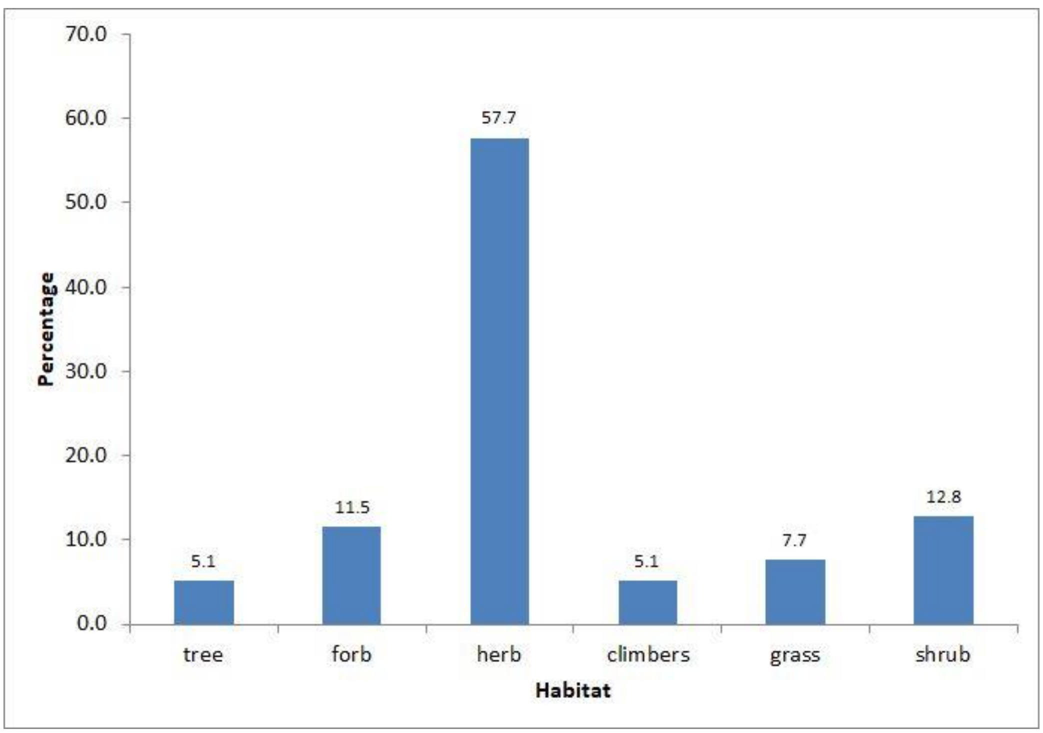

Figure 2: The habit of plant species in the dumpsite

Table 3: GPS coordinates for each quadrat throw

Block	Sampling site	GPS coordinates	Total number of species	Species diversity per sampling site
A	1	S00^{o}19.335’; E037^{o}39.545’; 1383m	9	0.36
	2	S01^{0}04.628; E037^{o}06.604’; 1410m	6	0.14
	3	S01^{o}04.628’; E037^{o}06.620’; 1423m	7	0.15
	4	S01^{0}04.597’; E037^{o}06.638’; 1455m	12	0.21
	5	S01^{o}04.590; E037^{o}06.660; 1470m	9	0.3
	6	S01^{o}04.625’; E037^{o}06.634’; 1471m	12	0.14
	7	S01^{o}04.612’; E037^{o}06.643’; 1473m	7	0.18
	8	S01^{o}04.591’; E037^{o}06.678’; 1476m	8	0.29
	9	S01^{o}04.612’; E037^{o}06.627’; 1479m	11	0.07
B	10	S01^{o}04.625’; E037^{o}06.665’; 1463m	5	0.19
	11	S01^{o}04.656’; E037^{o}06.657’; 1457m	5	0.17
	12	S00^{o}19.346’; E037^{o}39.554’; 1377m	6	0.10
	13	S01^{o}04.356’; E037^{o}06.614’; 1483	7	0.21

Presence of trees at the dumpsite showed that perhaps during ecological succession, seeds were carried from the surrounding areas to the dumpsite through either biological agents or wind (Yadav *et al*, 2022). However, only those plants that are tolerant to harsh environment are able to grow and survive in polluted sites. High species diversity is present at the dumpsite, as evidenced by the Shannon-Weaver diversity index of 0.94 (H' = 0.94); an indicator that the species are tolerant to the conditions at the dumpsite. However, the species evenness value of 0.45 also indicated that the amount of solid waste pollutants, the dumpsite's age, and its altitude might all have an influence on the species diversity at various sampling sites. A heterogeneous floral distribution may also be indicated by the Evenness Index (E = 0.45). A dumpsite's species richness has been found to be impacted by the accumulation of soil pollutants; heavy metals may inhibit cytoplasmic enzymes and cause oxidative stress-induced cell structure damage, which would impede plant growth (Chibuike *et al*., 2014). Nonetheless, it has been demonstrated that the age of the dumpsite has a major impact on the evenness and richness of species (Pyšek *et al*., 2003). Moreover, the low species evenness may indicates heterogeneous spread of wastes on the site following pressure on the surface due to the presence of pollutants and gases released when some wastes such as e-wastes are heated up as well as the age of the dumpsite (Messou *et al*., 2013). Hence, Kang’oki dumpsite has high species diversity because it is a recent dumpsite. However, a number of factors such as drainage, temperature, gaseous emission and the nature of the soils have also shown an impact on diversity of the plant taxa (Nagendran *et al*., 2006). Therefore, Kang’oki dumpsite present high diversity index for plants due to optimum temperatures, good drainage, and good soil conditions that support vegetative growth at the dumpsite. However, some species showed stunted growth, this indicates vulnerability of these plants to the prevailing environmental conditions (Nagendran *et al.*, 2006)

Heavy Metal Concentration in Soils

The study revealed that the concentration of all the selected heavy metals in the soil samples varied significantly (p <0.0001).

Cadmium concentration in soil samples collected from Kang'oki dumpsite ranged from ND to 1.63±0.030 mg/kg of soil with maximum concentration found at sampling site 12, which represented the abandoned part (Table 4). Samples from seven sampling sites showed cadmium concentration above WHO permissible level of 0.2 mg/kg. Nickel concentration ranged from 7.95±0.050 to 36.33±0.180 mg/kg of soil. Samples from all sampling sites showed nickel concentration above WHO permissible limit of 5 mg/kg. Copper concentration in the soils sample ranged from 3.41±0.050 to 121.18±0.500 mg/kg of soil for sampling site 13 and 3, respectively. Site 13 was in abandoned part of the dumpsite while site 3 consists of the active part of the dumpsite. Lead concentration in soils ranged 13.25±0.420 to 80.13±0.190 mg/kg for sites seven and five, respectively whereby both sites seven and five represented the active part of the dumpsite. The level of the Cadmium, nickel, lead and copper pollution was less in uncontaminated site compared to contaminated site. The average soil contamination in both contaminated and uncontaminated sites were in the sequence of Pb > Cu > Ni > Cd with mean concentrations of 39.89 mg/kg, 31.74 mg/kg, 17.11 mg/kg, 0.80, mg/kg, respectively.

Table 4: Concentration of the selected Heavy Metals in soil samples at the Kang'oki dumpsite and uncontaminated site

Sampling Sites	Cd (mg/kg)	Ni(mg/kg)	Cu(mg/kg)	Pb(mg/kg)
1	ND	10.03±0.080^{g}	4.73±0.040^{j}	19.50±0.110^{g}
2	0.29±0.000^{f}	19.76±0.230^{g}	17.10±0.080^{i}	42.62±0.150^{g}
3	0.58±0.020^{d}	18.15±0.07^{e}	121.18±0.500^{a}	62.63±0.610^{c}
4	0.98±0.020^{b}	21.77±0.140^{d}	83.29±0.380^{b}	76.69±0.960$^{a\ b}$
5	0.97±0.030^{b}	27.80±0.340^{b}	67.82±0.760^{c}	80.13±0.190^{a}
6	0.67±0.010^{c}	36.33±0.180^{a}	49.45±1.140^{d}	76.31±1.270^{b}
7	ND	8.29±0.110^{h}	5.10±0.320$^{k\ j}$	13.25±0.420^{i}
8	ND	15.39±0.310$^{f\ g}$	4.30±0.060$^{k\ j\ l}$	17.25±0.220^{h}
9	ND	16.24±0.437^{f}	25.43±0.450^{g}	36.06±3.485^{f}
10	ND	7.95±0.050^{h}	4.28±0.100$^{k\ j\ l}$	15.21±0.670$^{h\ I}$
11	0.19±0.100^{e}	14.20±0.080^{g}	36.01±0.770^{e}	46.06±0.143^{e}
12	1.63±0.030^{a}	22.44±0.050^{d}	30.35±0.120^{f}	37.19±0.690^{f}
13	ND	8.52±0.360^{h}	3.41±0.050^{l}	13.29±0.020^{i}
14(Uncontaminated	0.58±0.040^{d}	25.03±0.830^{c}	23.90±0.100^{h}	56.65±0.450^{d}
15(uncontaminated site)	ND	6.50±0.420^{i}	3.82±0.040$^{k\ l}$	12.19±0.020^{i}
Final mean	0.7999	17.1094	31.7377	39.8871
Permissible limits	3	100	50	50
LSD	0.0839	0.9656	1.3963	3.5002
CV	4.4343	2.6478	2.0641	4.1171

[a]Means followed by same letter in same columns are not significantly different at $\alpha = 0.05$, Values are means ± standard error (SE), and ND (Not detectable: these were samples with a particular heavy metal below detectable level).

Comparing the results of this study to those of Čudić et al. (2016), which revealed higher concentrations of Pb, Cd, Cu, and Ni in a dumpsite, this study found lower concentrations of these elements. The heavy metals concentrations in the soils at

Kang'oki dumpsite were high; this is could be partly attributed to the presence of e-wastes (speakers, batteries, cassettes, radio, extensions, mobile phones parts, and parts of broken bulbs) observed in the field (Fosu-Mensah *et al.,* 2017) and various industries around the dumpsite. Inoti *et al*. (2012) also argued that increased heavy metals concentration in soils from Thika municipality is attributed to effluents discharged from industries such as Royal paint industries, leather industries, Afroplast industries, BAT industries among other industries found in Thika and also from domestic and industrial wastes. Furthermore, the settlement along the uncontaminated site disposes their wastes in the dumpsite hence low heavy metals' concentration in uncontaminated sites. Obasi *et al*. (2015) found that metal concentration in the soils collected from dumpsites is significantly higher compared to uncontaminated sites. Tripathi and Misra (2013) also found elevated levels of Pb, Ni and Zn at the core of the dumpsite and lowest levels were observed a distance from the centre of the dumpsite indicating that as distance from the centre of the dumpsite increases, heavy metals concentration in soils decreases. The dumpsite soil had the highest concentration of lead compared with other metals. The elevated level of lead in the dumpsite soil could be due to the well-known lead sources such as industrial wastes enriched in Pb, paints, and municipal sewage (Owiti, 2015). Thika municipality is an industrialized municipality with various industries (Inoti *et al.,* 2012) such as BAT industry. Tobacco is known to produce smokes that are rich in heavy metals such as Pb, Cd, Ni, and Pb (Kaluli *et al.,* 2010). The industries such as manufacturing industries in many cases dispose of wastes containing pollutants in the biosphere which may result in a silent epidemic of metal poisoning in the surrounding environment (Yashim *et al*., 2016).

Heavy Metals Concentration in Selected Plant Tissues

The result of this study showed that there was significant differences ($p < 0.0001$) in concentration of Pb, Ni, Cu and Cd across sampling sites and plants tissues. However, at species level significantly different ($p = 0.0209$) in concentration of selected metals was observed only on copper among the four studied plant species. Cadmium accumulation values were between 0.44 to 0.70 mg/kg for *Cassia didymobotrya* and *Datura sramoniun*, respectively (Table 5). Cadmium concentration for all the plants was above the WHO permissible limit of 0.02 mg/kg for Cd in plants (Table 5).

Table 5: Concentration of selected heavy metals in selected plants species growing at Kang'oki dumpusite, Thika Municipality, Kenya

Plant species	Parameters			
	Cd (mg/kg)	Ni(mg/kg)	Cu(mg/kg)	Pb(mg/kg)
Datura stramonium	0.6939[a]	9.9090[bc]	10.8970[a]	13.2102[ab]
Parthenium hysterophorus	0.5224[b]	10.4204[b]	8.5358[b]	11.4812[b]
Ricinus communis	0.5148[b]	9.3140[c]	7.5029[b]	13.8590[a]
Cassia didymobotrya	0.4418[c]	11.3852[a]	3.7492[c]	13.1741[ab]
Mean	0.552972	10.23003	8.098197	12.74693
LSD	0.0602	0.6342	2.0266	1.7347
CV%	17.55587	10.00486	40.38605	21.96218
WHO permissible limits	0.02	10.00	10.00	2.00

[a]Means followed by same letter in same columns are not significantly different at $\alpha = 0.05$, Values given are means

Cadmium concentration was highest in the stem of *Datura stramonium* and lowest in the stem of *Cassia didymobotrya* with concentrations of 0.9781 mg/kg in location 11 and 0.3066 mg/kg in site 5, respectively (Table 6). Cadmium concentrations in soil samples from dumpsite were lower than its concentration in plants from the same dumpsite (Tables 4 and 5). This is an indicator that the plants growing in the dumpsite have greatest ability to remove cadmium from the soils by accumulating it in their tissues.

Accumulation of Nickel in the four selected plants ranged from 9.31 mg/kg to 11.39 mg/kg for *Ricinus communis* and *Cassia didymobotrya*, respectively (Table 5). The concentration of Ni in *Cassia didymobotrya* and *Parthenium hysterophorus* were above the WHO/KEBS permissible limit of 10 mg/kg (Table 5). Nickel concentration was found to be highest in the stem of Datura stramonium in sampling site 10 and lowest in the roots of *Datura stramonium* in sampling site 1 with mean concentrations of 16.6471 and 3.6514 mg/kg, respectively (Table 7).

Copper concentration in plants ranged from 3.75 mg/kg to 10.90 mg/kg for *Cassia didymobotrya* and *Datura stramoniun*, respectively (Table 5). Copper concentrations in the studied species except for *Datura stramonium* were below the permissible limit of copper of 10 mg/kg (Table 5). The leaves of *Datura stramonium* showed highest copper concentration of 22.0983 mg/kg at location 11 while lowest copper concentration of 0.1238 mg/kg was found in the roots of *Ricinus communis* at sampling site 8 (Table 8).

Lead accumulation in the studied plants ranged from 11.48 mg/kg to 13.86 mg/kg for *Parthenium hysterophorus* and *Ricinus communis*, respectively (Table 5). Lead concentrations in the selected plants were above the WHO permissible limit of lead in plants of 2 mg/kg (Table 5). Stem of *Datura stramonium* showed highest lead concentration of 22.0280 mg/kg at location 10 while roots of *Datura stramonium* showed lowest lead concentration of 7.0297 mg/kg at site 2 (Table 9).

Table 6: Concentration of *cadmium* in the selected plant tissues across sampling sites

Site	Species	Parts			BCF	TF
		Leaves	Stem	Roots		
1	*Datura stramonium*	0.62[ef]	0.58[efgh]	0.31[no]	-	2.0384[abc]
2	*Datura stramonium*	0.95[a]	0.66[de]	0.4208[jklm]	1.4509[b]	2.2540[ab]
3	*Parthenium hysterophorus*	0.5971[efg]	0.5484[fghi]	0.3506[lmno]	0.6044[cd]	1.7124[abcd]
4	*Ricinus communis*	0.4985[hijk]	0.6500[de]	0.3472[lmno]	0.3543[cd]	2.3335[a]
5	*Cassia didymobotrya*	0.6415[de]	0.3066[no]		0.5096[cd]	1.5802[abcd]
6	*Ricinus communis*	0.5489[fghi]	0.5500[fghi]	0.3271[mno]	0.4883[cd]	1.7315[abcd]
7	*Parthenium hysterophorus*	0.6113[efg]	0.7307[cd]	0.5215[ghij]	-	1.0897[de]
8	*Ricinus communis*	0.5981[efg]	0.6437[de]	0.4703[ijkl]	-	1.3246[cde]
9	*Parthenium hysterophorus*	0.4955[hijk]	0.4634[ijkl]	0.4709[ijkl]	-	1.2705[cde]
10	*Datura stramonium*	0.8045[bc]	0.8323[b]	0.5288[ghij]	-	1.1401[de]
11	*Datura stramonium*	0.9259[a]	0.9781[a]	0.7256[cd]	0.6768[a]	0.7200[e]
12	*Parthenium hysterophorus*	0.5938[efg]	0.7256[cd]	0.4948[hijk]	0.3036[d]	1.3957[cde]
13	*Cassia didymobotrya*	0.6019[efg]	0.5935[efg]	0.4650[ijkl]	-	1.5599[abcd]
14	*Parthenium hysterophorus*	0.5749[efgh]	0.3976[klm]	0.3925[klmn]	0.6768[d]	1.4647[bcd]e
15	*Cassia didymobotrya*	0.2619[no]	0.5250[ghij]	0.2778[no]	-	1.6540[abcd]
	LSD	0.0901				
	CV%	8.08072				

[a]Means followed by same letter are not significantly different at α = 0.05, Values are means in mg/kg, Species exhibiting the dash BCF had their rhizosphere soils with Cd concentration as ND.

Table 7: Concentration of Nickel in the selected plant tissues

Site	Species	Parts			BCF	TF
		Leaves	Stem	Roots		
1	*Datura stramonium*	6.6301^{rs}	6.0337st	3.6514^{u}	0.3551^{g}	1.8623^{a}
2	*Datura stramonium*	5.4715^{tu}	7.0455^{r}	4.6535^{u}	0.2356ij	1.1917^{efg}
3	*Parthenium hysterophorus*	9.6576^{op}	5.8081st	5.8428st	0.3220^{gh}	1.4816^{bc}
4	*Ricinus communis*	6.9506^{r}	9.2500^{no}	5.8565st	0.2690^{hi}	1.1894^{efg}
5	*Cassia didymobotrya*	8.8088^{op}	5.2830^{tu}	8.4580^{mno}	0.2041^{j}	1.5523^{b}
6	*Ricinus communis*	10.1008^{lm}	11.0750^{jk}	7.2196^{qr}	0.1987^{j}	1.3994^{bcd}
7	*Parthenium hysterophorus*	9.0954^{no}	10.1358^{lm}	9.9865^{pq}	0.9635^{d}	1.1388^{fg}
8	*Ricinus communis*	12.0863^{ghi}	11.6089^{ij}	9.6782^{mn}	0.6289^{e}	1.2497^{def}
9	*Parthenium hysterophorus*	10.9256^{jkl}	10.8526^{jkl}	10.7317^{kl}	0.6610^{e}	1.0182^{g}
10	*Datura stramonium*	14.5409^{c}	16.6471^{a}	12.1394^{ghi}	1.5276^{b}	1.1990^{efg}
11	*Datura stramonium*	13.5708^{de}	15.7717^{b}	12.8423^{efg}	0.9044^{d}	1.0571^{g}
12	*Parthenium hysterophorus*	13.6566^{de}	12.9855^{ef}	10.9847^{jk}	0.4895^{f}	1.2440^{def}
13	*Cassia didymobotrya*	13.6511^{de}	13.0239^{ef}	12.2811^{fghi}	1.4416^{c}	1.1311^{fg}
14	*Parthenium hysterophorus*	12.5793^{fgh}	14.1415^{cd}	11.9223^{hi}	0.4764^{f}	1.0566^{g}
15	*Cassia didymobotrya*	14.96^{bc}	12.03^{ghi}	11.05^{jk}	1.70^{a}	1.36^{cde}
	LSD	0.8407				
	CV%	4.077603				

[a]Means followed by same letter in same columns are not significantly different at $\alpha = 0.05$, Values are means in mg/kg.

Table 8: Concentration of *Copper* in the selected plant tissues

Site	Species	Parts			BCF	TF
		Leaves	Stem	Roots		
1	*Datura stramonium*	13.5593[g]	6.0096[p]	5.8727[p]	1.2419[d]	0.4608[e]
2	*Datura stramonium*	20.8168[c]	4.1591[s]	8.2178[m]	0.4567[e]	0.1649[h]
3	*Parthenium hysterophorus*	4.0000[s]	4.2307[rs]	8.3646[m]	0.0690[g]	0.1194[i]
4	*Ricinus communis*	9.7908[k]	4.0000[s]	4.0741[s]	0.0489[g]	0.1080i
5	*Cassia didymobotrya*	8.3646[m]	4.6462[q]		0.0819[g]	0.0932[i]
6	*Ricinus communis*	21.0247[c]	10.6750[j]	11.5421[i]	0.2334[fg]	0.2603[g]
7	*Parthenium hysterophorus*	14.4743[f]	11.7858[i]	15.7598[e]	3.0903[a]	0.7513[c]
8	*Ricinus communis*	4.9343[q]	1.3614[v]	0.1238[w]	0.1155[g]	0.6644[d]
9	*Parthenium hysterophorus*	10.5788[j]	0.5609[w]	1.2499[u]	0.1121[g]	0.2838[g]
10	*Datura stramonium*	17.4442[d]	10.6247[j]	9.8318[k]	2.2981[c]	0.8659[b]
11	*Datura stramonium*	22.0983[a]	5.6729[p]	6.4579[o]	0.1793[fg]	0.2794[g]
12	*Parthenium hysterophorus*	12.5927[h]	1.3482[w]	5.7150[p]	0.1883[fg]	0.3559[f]
13	*Cassia didymobotrya*	4.4392[rs]	1.3810[v]	0.4355[w]	0.2305[fg]	1.1635[a]
14	*Parthenium hysterophorus*	21.5022[b]	3.5288[t]	7.6538[n]	0.3203[ef]	0.2512[g]
15	*Cassia didymobotrya*	3.4473[t]	1.5250[v]	8.8462[l]	2.4978[b]	0.8294[b]
	LSD	0.4460				
	CV%	2.733003				

[a]Means followed by same letter in same columns are not significantly different at α=0.05, Values are means in mg/kg.

Table 9: Concentration of Lead in the selected plant tissues

Site	Species	Parts			BCF	TF
		Leaves	Stem	Roots		
1	*Datura stramonium*	15.6032^{efg}	8.6538^{no}	8.9859^{mn}	0.4608^{e}	1.7390^{a}
2	*Datura stramonium*	13.0820^{ij}	9.9089^{lm}	7.0297^{q}	0.1649^{h}	1.8774^{a}
3	*Parthenium hysterophorus*	10.7474^{kl}	7.4035^{pq}	7.4787^{opq}	0.1194^{i}	1.4396^{b}
4	*Ricinus communis*	7.5486^{opq}	10.8250^{kl}	8.2826^{no}	0.1080i	0.9118^{f}
5	*Cassia didymobotrya*	13.3735^{hij}	8.4193^{no}		0.0932^{i}	1.7913^{a}
6	*Ricinus communis*	19.6778^{b}	13.4250^{hij}	19.8598^{b}	0.2603^{g}	0.9909^{ef}
7	*Parthenium hysterophorus*	14.5478^{gh}	11.6208^{k}	9.9536^{lm}	0.7513^{c}	1.4656^{b}
8	*Ricinus communis*	16.6218^{cdef}	17.0297^{cd}	11.4604^{k}	0.6644^{d}	1.4503^{b}
9	*Parthenium hysterophorus*	13.3040^{ij}	10.0966^{lm}	10.2359l	0.2838^{g}	1.2997^{bcd}
10	*Datura stramonium*	16.1647^{def}	22.0280^{a}	13.1731^{ij}	0.8659^{b}	1.2273^{cd}
11	*Datura stramonium*	14.2287^{hi}	16.7987^{cde}	12.8664^{j}	0.2794^{g}	0.1068^{def}
12	*Parthenium hysterophorus*	17.1945^{cd}	13.7381^{hij}	13.2333^{ij}	0.3559^{f}	1.2992^{bcd}
13	*Cassia didymobotrya*	17.7677^{c}	16.0004^{def}	15.4614^{fg}	1.1635^{a}	1.1061^{def}
14	*Parthenium hysterophorus*	15.7989^{ef}	0.3750^{r}	14.2283^{hi}	0.2512^{g}	1.1110^{de}
15	*Cassia didymobotrya*	13.5258^{hij}	13.0000^{ij}	10.1068^{lm}	0.8294^{b}	1.3376^{bc}
	LSD	1.2163				
	CV%	4.7347				

[a]Means followed by same letter in same columns are not significantly different at α=0.05, Values are means in mg/kg of soil.

The concentration of the selected metals varied significantly in the studied plants with lead being the highest and cadmium the lowest The four studied plants showed different concentration for Cd, Pb, Cu and Ni, implying that the four plants have different accumulation potential for the selected heavy metals. Inoti *et al*. (2012) also found that different plants have different heavy metal accumulation potential. These differences in heavy metal uptake by plants can be attributed to differences in the ability of the plants to accumulate the metals and also differences in tolerance to various heavy metals. The low level of cadmium is attributed to high toxicity effect of cadmium in plants (Anderson et al., 2004) and faster mobility and percolation ability of cadmium compared to other heavy metals such as Pb and Cu (Eludoyin *et al.*, 2017). However, the lower concentration of lead is attributed to lack of its unavailability due to high affinity to organic matter.

The findings of this study showed that *Datura stramonium* had the highest accumulation for Cd and Cu. This is an indicator that it is the most efficient accumulator for Cd and Cu. According to studies by Ibrahim et al. (2013); Tripathi and Misra (2013), *D. stramonium* significantly exhibits positive potential for phytostabilization of soils contaminated by Cu, Cd, and Pb. *Ricinus communis* also showed great potential for higher accumulation of Cd and Pb in this study. *Ricinus communis* grows in disturbed areas such as wasteland, hence used as an indicator of Cd and Pb pollution (Yashim *et al.*, 2016). Since *Ricinus communis* has potential for cadmium, nickel and lead accumulation, it can be used for phytoremediation of Cd, Pb contaminated soils (Huang *et al*., 2011; Yashim, 2012; Tripathi & Misra, 2013; Yashim *et al.*, 2016). Similarly, *Parthenium hysterophorus* showed potential to accumulate significant amount of cadmium, copper, nickel and lead. Tariq *et al*. (2018) reported *P. hysterophorus* to have ability to significantly uptake Cd, Cu, and Ni from contaminated environment. Tariq *et al*. (2018) further argues that *Parthenium hysterophorus* has been sturdied to grow in a highly polluted environment and a possible explanation for this is that *P. hysterophorus* is able to tolerate the heavy metal pollution in wastelands and thus, have bioremediation potential of highly contaminated.

Concentration of Cd, Ni, Cu, Pb in the Plant Tissues

There was significant differences ($p < 0.0001$) in the concentration of Cd, Cu, Ni, and Pb in the studied plants parts across the sampling sites. This suggests that each plant tissue exhibit differences in heavy metal accumulation potential. The concentration Pd, Cu, Ni and Cd in the plants' tissues was higher in both contaminated and uncontaminated sites which are an indicator that the dumpsite expanded with increasing waste flux from various sources.

The concentration of Cd, Ni, Cu and Pb in leaves, stem, and roots differed significantly ($p < 0.05$) in the studied plant species. This indicates that the plants part has different accumulation potential for heavy metals. Cadmium concentration in the different parts of *Datura stramonium, Parthenium hysterophorus, Cassia didymobotrya* and *Ricinus communis* ranged from 0.4396 mg/kg to 0.6346 mg/kg for roots and leaves, respectively (Table 10). Concentrations of Cd in leaves stem and roots were above the WHO/KEBS permissible limit of 0.02 mg/kg (Table 5). This shows that the studied plants are contaminated by Cd and risk of

Cd exposure. Nickel concentration in the parts of the studied plants ranged from 8.8880 mg/kg to 10.7792 mg/kg for roots and stem, respectively (Table 10). Nickel accumulation in the studied plant tissues were above WHO/KEBS permissible limit of 10mg/kg apart from roots (Table 5). Copper concentration in different parts of the studied species ranged from 4.9793 mg/kg to 12.7761 mg/kg for stem and leaves, respectively (Table 10). Stems and leaves exhibited concentrations below permissible limits while copper concentrations in leaves were above WHO/KEBS permissible limit of 10 mg/kg (Table 5). Lead concentration in the studied plants tissues ranged from 11.301 mg/kg to 14.480 mg/kg for roots and leaves and roots respectively (Table 10). All the tissues showed Pd concentration above the WHO/KEBS permissible limit of 2 mg/kg (Table 5).

Table 10: Concentration of studied heavy metals on parts of all selected species

Parameter	Species parts	Concentration (mg/kg)	LSD	CV	Mean
Cd (mg/kg)	Leaves	0.6346[a]	0.0791	27.83030	0.550834
	Stem	0.5811[a]			
	Roots	0.4396[b]			
Ni(mg/kg|)	Stem	10.7792[a]	1.6674	32.00522	10.09189
	Leaves	10.6884[a]			
	Root	8.8880[b]			
Cu(mg/kg)	Leaves	12.7761[a]	2.5455	60.63552	8.132062
	Ro	6.8015[b]			
	Stem	4.9793[b]			
Pb(mg/kg)	Leaves	14.4804[a]	2.0213	31.16448	12.56426
	Stem	11.9548[b]			
	Root	11.3016[b]			

[a]Means followed by same letter in same columns are not significantly different at $\alpha = 0.05$, Values are means ±S.E.

In comparison to their roots and stems, the leaves of *Datura stramonium, Parthenium hysterophorus, Ricinus communis*, and *Cassia didymobotrya* showed higher accumulations of Cd, Cu, and Pb, with the exception of Ni (Table 10). These findings are in agreement with those of Yashim *et al*. (2016) who found out that *Ricinus communis* stem and leaves accumulated significantly higher amount of Pb, Cd and Ni than the root. A variation in the metal concentrations in different plants tissues was also evident in the current study (Table 10) which could be as a result of mobility of Pb, Ni, Cd, and Cu. A similar pattern, of plants accumulating higher Cd and Pb in their leaves compared to their roots was also revealed in a study by Ibrahim (2013). Plants roots usually remove heavy metals and essential nutrients from the soil; transport them to the leaves through stems for harvesting or even disposal, hence, lowering concentration of heavy metals in the roots of the plants (Yashim *et al.*, 2016).

Conversely, a study conducted by Badr *et al.* (2012) on Cassia spp. revealed that the plant's leaves accumulated less heavy metal than the corresponding roots, with the exception of cadmium. A study by Lorestani *et al*. (2011) also showed that roots of native plants accumulate higher amount of Cu compared to their leaves. A possible explanation for these findings that are in disagreement with the current study is that the roots are the origin where bioavailable metals come in contact with plants. The roots, therefore, absorb the heavy metals and accumulate them thus increasing the concentration at the root level. Considering the current study, the metals might have been transferred to stems and leaves reducing their concentration in the root level.

The Interspecies Comparison of the Concentration of the Selected Heavy Metals

The BCF and the TF for the selected plants varied significantly ($P < 0.001$) across the sampling sites. The significant variations in the TF and BCF of the selected plant species indicate that these plant species have different phytoremediation potential. The BCF for cadmium ranged from 0.4213 mg/kg to 2.6348 mg/kg in *Ricinus communis* and *Datura stramonium,* respectively (Table 11). The TF ranged from 1.3866 mg/kg to 1.7965 mg/kg in Parthenium hysterophorus and *Ricinus communis*, respectively (Table 11. This reveals that the four studied plants are efficient for translocation of Cd from roots to leaves. The BCF for nickel ranged from 0.3655 mg/kg to 1.1153 in *Cassia didymobotrya* and *Ricinus communis* respectively. The TF ranged from 1.1878 mg/kg to 1.3465 mg/kg in *Parthenium hysterophorus* and *Cassia didymobotrya*, respectively (Table 11). The BCF for copper ranged from 0.1326 mg/kg to 1.0440 in *Ricinus communis* and *Datura stramonium* respectively. The TF ranged from 1.1633 mg/kg to 4.7211 mg/kg in *Casssia didymobotrya* and *Ricinus communis* respectively (Table 11). The BCF for lead ranged from 0.3442 mg/kg to 0.6964 mg/kg in *Ricinus communis* and *Cassia didymobotrya* respectively. The TF ranged from 1.1177 mg/kg to 1.4876 mg/kg respectively (Table 11). *Datura stramonium and Ricinus communis* showed BCF more than 1 for the selected heavy metals. *Datura stramonium* showed BCF of 2.6348 for Cd and 1.0440 for Cu (Table 11). This indicates that *Datura stramonium* has the ability for phytoremediation of Cd and Cu-contaminated sites. *Ricinus communis* showed BCF of 1.1878 for nickel (Tables 11) indicating that the species can be used to phytoremediate the soils contaminated with nickel. All the four plants showed TF greater that one (Table 11) indicating that all the four studied plants effectively translocate cadmium, nickel, copper, and lead from their roots to shoot and are therefore able to uptake and accumulate heavy metals from the soil.

Table 11: The interspecies comparison of the selected heavy metals concentration

Parameters	*D. stramonium*		*P. hysterophorus*		*R. communis*		*C. didymobotrya*	
	BCF	TF	BCF	TF	BCF	TF	BCF	TF
Cd	2.6348	1.5381	0.5283	1.3866	0.4213	1.7965	0.5096	1.5980
Ni	0.7557	1.3277	0.5825	1.1878	1.1153	1.2795	0.3655	1.3465
Cu	1.0440	2.2105	0.7560	2.0280	0.1326	4.7211	0.9366	1.1633
Pb	0.4427	1.4876	0.3523	1.3225	0.3442	1.1177	0.6964	1.4117

Based on the criteria for identifying phytoaccumulators suggested by Mganga *et al.* (2011), *Datura stramonium* showed BCF and TF both greater than one for Cadmium and copper hence it can be potentially utilizedd in phytoextraction of Cd and Cu. *Ricinus communis showed* both bioaccumulation and translocation factors greater than one for Nickel hence it can be utilized in phytoextraction of Ni from polluted sites.

Plants with translocation factors (TFs) and bioaccumulation factors (BCFs) greater than one have the potential for phytoextraction, whereas plants with TFs less than one and BCFs greater than one have the potential for phytostabilization (Nouri *et al*., 2011; Shittu *et al*., 2015). Thus, in light of this study's findings, *R. communis* can be used to remove a higher concentration of Ni. A study by Kiran and Prasad (2017) revealed that *R .communis* can effectively remove Cd, Ni and Pb from heavy metal contaminated soils more than the known hyperaccumulators such as Brassica Juncea following its large amount of the underground and above ground biomass. *Yashim et al.* (2016) also found *R. communis* to have BCF for Cd and Ni >1 and TF for Pb, Ni, Cd >1 while BCF for Pb was <1. The findings are in agreement with the results of this current study except for Cd. Cadmium is normally low in soil which may affect its levels in plants (Yashim *et al*., 2016). However, *Ricinus communis* ability to hyperaccumulate Pb was not evident in this study. This is probably because Pb has a high metal affinity in the organic matters limiting its availability for plant uptake (Zehra *et al*., 2009). Some plants may be tolerant to heavy metal and so grow well in heavy metal contaminated soils but still show very low BCF. This could be due to unavailability of some heavy metals such as cadmium and lead allowing their high-affinity nature in the organic matter. These heavy metals tolerant plants however, can still be suggested for bioremediation of heavy metal polluted sites and site restoration due to their tolerance mechanism. For example, *Cassia spp* has been studied by Badr *et al*. (2012) to have efficiency for translocation of lead from roots to shoot. From this study *P. hysterophorus and C. didymobotrya* showed low BCF for the selected heavy metals.

Conclusion

Phytoremediation is a new tool or technique which has attracted attention of various scientists globally. The present study aimed to assess the potential of the four studied plants in removal of the selected heavy metals in the dumpsite. Phytoremediation has become the most popular approach for remediating heavy metal-contaminated soils in recent years. From this study, Kang'oki dumpsite presented high floristic diversity. The dumpsite harbor important plants, both native and exotic plants which are an indicator that these plants are tolerant of extreme conditions in the dumpsite such presence of heavy metals. *Datura stramonium* and *Ricinus communis* showed BCF and TF both greater than one for Cd, Cu and Ni respectively indicating these plants can be best utilized for phytoextraction of the heavy metals. However, all the plants showed TF greater than one indicating that these plants have good Translocation for heavy metals; hence, they can be used for remediation of sites contaminated by heavy metals. In comparing heavy metals concentration in soils and plants samples obtained from contaminated sites and uncontaminated sites, there was noticeable difference in the concentration in the two sites. The contaminated sites showed higher concentration than the uncontaminated sites; however, there was presence of heavy metals in the samples collected from the uncontaminated sites. This demonstrates that there is a possibility of overexposure of the selected heavy metals. The heavy metals in the dumpsite could be affecting the uncontaminated area when the metals are carried from the dumpsite through surface run-off.

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Declaration and competing interest

There authors declare that there is no potential competing interests.

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