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PHYTOREMEDIATION OF HEAVY METALS FROM LANDFILL SOIL USING *Polyscias fruticosa*

Durumin Iya, N. I.,[1, 2*], Assim, Z. B. [1], Omorinoye, O. A., [1,4] and Asare, E. A.[1,3]
[1]Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia
[2]Department of Chemistry, Faculty of Science, Federal University Dutse, Ibrahim Aliyu Bye-Pass, 7156, Dutse, Jigawa State, Nigeria
[3]Department of Nuclear Sciences and Applications, School of Nuclear and Allied Sciences, University of Ghana
[4]Department of Geology and Mineral Sciences, Faculty of Physical Sciences, University of Ilorin, Nigeria
*Corresponding author: +2348137527230 nasduruminiya@fud.edu.ng

ABSTRACT
The presence of heavy metals in landfill soil by industrial or anthropogenic activities pose a risk to the environment and it is one of the major concerns. This study was to determine and evaluate the capability of Polyscias fruticosa in the phytoremediation of heavy metals from abandoned landfill soil. P. fruticosa was analysed to evaluate its tolerance and phytoremediation ability on landfill soil in a greenhouse study with a harvesting period of 1-month intervals. Ninety-six (96) cuttings from P. fruticosa were transplanted and had the same treatment in 500 g landfill soil. The roots, stems, and leaves of exposed and unexposed plants were dry-digested and heavy metals were determined using Atomic Absorption Spectrophotometer (AAS). The height and weight of dry biomass of exposed and unexposed plants were determined. The data obtained were subjected to a one-way analysis of variance and the least significant difference (L.S.D.) at probability level p<0.05. The highest accumulation in the roots occurred on Pb, followed by Cr, As, and Cd with concentrations 0.82, 0.68, 0.35, and 0.33 mg/kg, respectively. Heavy metals were not detected from unexposed plant and soil. The three indices, bioconcentration, translocation factors, and extraction coefficient, were found to be more significant (>1) on six months compared to other harvesting periods. The percentage removal was Cd 88%, As 87%, Cr 86%, and Pb 78%. The results indicate that P. fruticosa might be an effective species to reduce heavy metals from landfill soil.
Keywords: Heavy metals; bio-concentration factor; percentage removal; Landfill soil; phytoremediation, Polyscias fruticosa.

INTRODUCTION

Sanitary landfills and open waste dumping sites dominate the solid waste disposal management system in most developing countries (Latifah *et al.*, 2009). Limited technical support and financial resources are the major sanitary landfills operating in low or middle-class income in developing countries (USEPA, 1998). These sanitary landfills lack environmental suppressing or abatement measures, such as covering materials on the bottom surface of the landfill, sufficient facilities for protection, and leachate treatment plants. Lack of environmental standards has imposed several contaminations on the environment, especially soil and water. Soil contaminations from landfills initiated by percolated liquid have passed through several chemicals and convey to the bottom of the earth by absorption and movement process (Ismail *et al.*, 2015). Long ago, "some Malaysian landfills lack abatement measures and inadequate leachate collection system such has caused significant metal pollution from leachate and the soil has become the main sink for the contaminated leachate" (Barasarathi *et al.*, 2021).

Heavy metal contamination is due to the movement of leachate from and within the landfill's waste cell. The release of heavy metals such as Pb, Cd, Cr, and Hg into the environment is a severe environmental concern and make trouble to public health and safety. There are two main groups of heavy metals, essentials such as Cu, Zn, and non-essentials such as As, Cr, Pb, Hg, Cd (Durumin Iya *et al.*, 2018).

The toxicity of non-essential heavy metals affects the production of antioxidant enzymes, photosynthetic system, and synthesis of plant chlorophyll (Milone *et al.*, 2003). Phytoremediation is a technology in which several plant species can uptake, accumulate, and translocate heavy metals to arial parts and separate the heavy metals into non-metabolic-active organs in less toxic forms (Kupper *et al.*, 2007). However, heavy metals such as Pb, Cd, Cr, and As chosen for this research study are more toxic and hazardous.

Identifying a suitable plant type is necessary for successful phytoremediation. And the plant should have a proper and distinguishable feature (Massa *et al.*, 2010). *P. fruticosa* plant is from the family of Araliaceae, which is standard and available widely, especially in South-Eastern Asia and some countries of the pacific region. This plant was chosen for this study because an information about its capability in phytoremediation is limited. And also, because of the plant ability to produce a sound root system, more biomass, and tolerate heavy metals contaminated soil (Durumin Iya *et al.*, 2019).

This study focuses on assessing the suitability of the plant in the phytoremediation of landfill soil. The specific objectives of the research were (1) to assess the biomass produce by the plants within the experimental period (2) assess the plant's potential in the uptake and transfer of the heavy metals. This study's contribution is the plant's capability to survive, uptake, and transfer heavy metals from landfill soil within a given time interval in a greenhouse growth condition.

MATERIALS AND METHODS

The experiment was conducted within six months from 23rd February 2018 to 30th September 2018 just to allow the plant grow fully under a greenhouse setting located at the Faculty of Resource Science and Technology of Universiti Malaysia Sarawak (Unimas). The GPS is N 010 33' 03.6 " E 1100 45' 56.5" at 1.2 km above sea level, under natural light, temperature of 27 - 33 ^{0}C, and 65 - 89% relative humidity. The soil sample was collected from Matang (N 01 034' 56.6" and E 110 0 14' 39.2"), an old landfill site about 16.00 km away from Universiti Malaysia Sarawak. Five to twenty (5-20) cm depth of the soil was collected from 5 different points using a plastic scoop and placed in a plastic container. When dried, the soil samples were thoroughly mixed and used for the study.

Plant propagation and Pot experiment

Young and healthy plants were collected from within the Universiti nursery and heavy metals analysis was carried out. One hundred and twenty (120) plant cuttings were made (approximately 4.0 - 4.2 cm height), planted on the sand, and watered three times a week. After propagation, a healthy and well-grown plant of approximately the same height were selected and transplanted into polyethene bags (one plant per bag) containing 500 g of landfill soil. Plants were watered 3 times a week and monitored throughout the experimental period of 6 months and harvested at intervals of one month. Eight replicate plants were made for each harvesting period, and another set of eight replicate plants was created as a control (unexposed plant). Thus, each harvesting period contains a collection of exposed and unexposed plants. The total number of exposed and unexposed plants used in the research were ninety-six (96) pieces.

Physicochemical analysis of soil samples

The pH of the soil was tested according to the procedure explained in Black (1973), while electrical conductivity (EC) was conducted as described by Rayment and Higginson (1992). The chemical oxygen demand (COD) analyses were performed according to standard analytical methods described in APHA (1995), with some modification in using $K_2Cr_2O_7$ to oxidize the sample at 150 ºC for 2:15 hours; the sample was analysed at 420 nm using a spectrophotometer HACH DR2000 at room temperature. Spectro photo-colourimetry was used for NH_4^+, a 10 ppm NH_3 was prepared by diluting 1 mL of NH_3 standard solution (1000) to 100 mL mark of volumetric flask (100 mL) with distilled water. A calibration curve was prepared. Nessler's reagent was also prepared with a double distilled water because normal distilled water may contain some traces of NH_3. 1 mL of Nessler's reagent was added to 5.0 mL of soil sample solution in the test tube and was allowed to stand for 10 min. It was then read at 366 nm with spectrophotometer model Hach DR1900 portable (McMullan, 1971). The biochemical oxygen demand (BOD) 5-day test was carried out (Young *et al.*, 1981) described with no modification. Moisture, organic matter, and ash contents were determined by following the procedure described in standard methods ASTM (2000).

Soil and Plant analysis

Big-sized particles were removed from the landfill soil sample through a sieve of 63 µm mesh model BS 410-1 (79-2070) stainless steel. The study was conducted following the experimental method described (Durumin Iya *et al.,* 2019), with some modifications. First, the sieved soil was digested (dry ashing), where crucibles with 1.0 gram of soil were heated in a muffle furnace to ash at 500 ^{0}C for 4 hours 30 min. Next, deionized water and concentrated nitric acid were added (1.0 mL each), then evaporated to dryness on a hot plate and heated at 400 ^{0}C for 15 min in a muffle furnace. Next, deionized water and concentrated hydrochloric acid were added and then evaporated to dryness on a hot plate. A volume of 25 mL deionized water was added to the sample, and filtered with a 0.45-micron filter into a flask. Heavy metals concentrations present in soil were determined using Atomic Absorption Spectrometer (AAS) Model Optima 8300 series. Before analysis, plant samples were removed and washed with distilled water to remove any soil deposit. It was then divided into root, stem, and leaf and dried in an oven for 48 hours at 60 ^{0}C (Ugolini *et al.*, 2013). Dried plant parts were ground and analysed according to the procedure described (Durumin Iya *et al.*, 2018). Heavy metals concentrations present in plant parts were determined using Atomic Absorption Spectrometer (AAS) model Optima 8300 series. Three indices such as bioconcentration factor (BCF), translocation factor (TF), extraction coefficient (EC) were used to evaluate the plant's potential in heavy metals phytoextraction (Karam *et al.*, 2016). The BCF is the ratio of heavy metal accumulation in plant root and soil. TF values were obtained by dividing the heavy metal concentrations in a shoot by that accumulated in the root (Soda *et al.*, 2012). The EC was obtained by the ratio of heavy metals accumulated in plant shoots and soil (Andreazza *et al.*, 2015).

$$BCF = \frac{metal\ in\ plant\ root}{metal\ in\ soil} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

$$TF = \frac{metal\ in\ plant\ shoot}{metal\ in\ root} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

$$EC = \frac{metal\ in\ shoot}{metal\ in\ soil} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

Removal (%) of heavy metals was calculated as expressed in Pandey *et al.* (2008):

$$R(\%) = \frac{Ci - Cf}{Ci} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4)$$

Ci and Cf represent the initial and final concentrations of heavy metals at the beginning of the study and at time f, respectively. The data generated in this study were subjected to a one-way analysis of variance (ANOVA) and expressed as group means (8 replicates) standard error (SE) analysed using Excel. The significant differences in the average were tested by the least significant difference (LSD) test at a 5% level of probability ($p < 0.05$).

RESULTS

Table 1 shows some physical and chemical parameters obtained from the analysis of landfill soil sample. The results were compared with the Standard (Environmental Quality Regulations 2009, Malaysia, E.Q.R. 2009). The plant survived and grow on landfill soil within the study period. Plant height, weight, and stem diameter of each harvesting period were presented in Table 2. The result obtained from AAS analysis shows that *P. fruticosa* parts had a varying concentration of heavy metals at different harvesting periods. The accumulation of each heavy metal detected in the plant parts based on their harvesting periods was presented in Tables 3, 4, 5, and 6 for As, Cd, Pb, and Cr, respectively, with the significant at $p < 0.05$ level.

Table 1: Characteristic parameters of landfill (exposed) soil, control (unexposed) soil and EQR 2009 standard

Parameters	Characteristics of the soil used as control (unexposed)	Characteristics of Matang abandoned Landfill soil	Standard (Environmental Quality Regulations 2009, Malaysia)
pH	7.2±0.03	7.86±0.08	6.0-9.0
E.C. µS/m	198±11.63	1208±32.12	-
Moisture content %	0.24±0.08	0.58±0.06	-
Total organic matter %	0.13±0.04	1.39±0.09	-
Ash content %	99.73	99.02±0.28	-
BOD (mg/L)	2.11±0.32	72.04±6.12	20.0
COD (mg/L)	87.62±2.01	698.62±9.35	400.0
S Solids (mg/L)	28.15±1.64	230.34±5.22	-
Ammonia-N [mg/L NH^{3}-N]	nd	210.42±6.58	5.0
Cadmium mg/L	nd	0.86±0.01	0.01
Chromium mg/L	nd	3.83±0.14	0.20
Lead mg/L	nd	3.51±0.15	0.10
Arsenic mg/L	nd	1.61±0.03	0.05
Temperature ^{0}C	14	26	-

The standard (Environmental Quality Regulations 2009, Malaysia) was reported by Fauziah *et al.* (2017). The pH value of landfill soil was within the range, but all other parameters were above the guideline standard. The parameters control (unexposed) soil was all within the standard range. Parameters with nd means not detected

Table 2. Height, stem diameter, dry biomass of *P. fruticosa* plant parts on different harvesting period (n=8)

Harvesting period	Height (cm)		Diameter (cm)		Root (mg)		Shoot (mg)	
	Exposed pant	Unexposed plant	Exposed plant	Unexposed plant	Exposed plantl	Unexposed plant	Exposed plant	Unexposed plant
1 month	30.24±0.62	29.63±0.79	0.93±0.00	0.91±0.01	1.09±0.04	1.01±0.01	4.01±0.11	3.82±0.04
2 months	32.81±0.99	31.03±	0.95±0.02	0.93±	1.25±0.03	1.18±	4.14±0.19	3.98±
3 months	33.91±0.82	32.98±	1.12±0.03	1.08±	1.37±0.02	1.32±	4.38±0.08	4.22±
4 months	35.38±1.13	34.57±	1.36±0.09	1.24±	1.61±0.10	1.57±	4.76±0.71	4.51±
5 months	37.69±2.07	36.08±	1.53±0.06	1.41±	1.82±0.03	1.76±	4.95±0.23	4.69±
6 months	39.12±1.64	38.11±	1.75±0.11	1.59±	1.96±0.26	1.91±	5.23±0.98	4.98±

Mean values ± standard deviation (n = 8).

Table 3: Concentration of As in landfill exposed soil, unexpsed soil and *P. fruticosa parts* (exposed and unexposed) (n=8)

Harvesting period	Soil		Plant Root		Plant Stem		Plant Leaves	
	Exposed	Un	Exposed	Un	Exposed	Un	Exposed	Un
1 month	1.41±0.04	nd	0.17±0.03	nd	0.08±0.01	nd	0.29±0.10	nd
2 months	1.23±0.03	nd	0.20±0.01	nd	0.10±0.03	nd	0.45±0.03	nd
3 months	0.98±0.09	nd	0.23±0.04	nd	0.12±0.01	nd	0.53±0.06	nd
4 months	0.42±0.42	nd	0.27±0.06	nd	0.14±0.01	nd	0.58±0.13	nd
5 months	0.21±0.03	nd	0.33±0.01	nd	0.16±0.04	nd	0.74±0.15	nd
6 months	0.19±0.01	nd	0.35±0.06	nd	0.17±0.06	nd	0.76±0.21	nd
$LSD_{0.05}$	-		0.519		0.225		0.745	

Values are means ± S.D. of 8 replicates. The mean values of root, stem, and leaves were statistically analyzed using a one-way analysis of variance (ANOVA). Since $F_{critical}$ (3.6823) > F (22.9824), this shows that the means are not significantly different at the probability of 0.05 and df 17. The Fisher's L.S.D. Indicates that at least one of the mean concentration from the root, stem and leaves is statistically different. The critical value is 2.1314. Parameters with nd means not detected, Un = unexposed

Table 4: Concentration of Cd in landfill exposed soil, unexposed soil and *P. fruticosa* parts (exposed and unexposed) (n=8)

Harvesting	Soil		Plant Root		Plant Stem		Plant Leaves	
period	Exposed	Un	Exposed	Un	Exposed	Un	Exposed	Un
1 month	0.82±0.03	nd	0.11±0.01	nd	0.08±0.00	nd	0.05±0.00	nd
2 months	0.36±0.04	nd	0.18±0.02	nd	0.12±0.01	nd	0.09±0.01	nd
3 months	0.29±0.02	nd	0.22±0.01	nd	0.15±0.01	nd	0.13±0.02	nd
4 months	0.22±.02	nd	0.27±0.03	nd	0.19±0.02	nd	0.16±0.01	nd
5 months	0.13±0.01	nd	0.31±0.01	nd	0.23±0.01	nd	0.20±0.03	nd
6 months	0.09±0.00	nd	0.33±0.2	nd	0.24±0.01	nd	0.21±0.01	nd
$LSD_{0.05}$	-		0.167		0.118		0.049	

Values are means ± S.D. of eight replicates. The mean values of root, stem, and leaves were statistically analyzed using a one-way analysis of variance (ANOVA). Since $F_{critical}$ (3.6823) > F (2.9946), this shows that the means are not significantly different at the probability of 0.05 and df 17. The Fisher's L.S.D. Shows that at least one of the mean concentration from the root, stem and leaves is statistically different, the critical value is 2.1314. Parameters with nd means not detected
Un = unexposed

Table 5: Concentration of Pb in landfil exposed soil, unexposed soil and *P. fruticosa* parts **(exposed and unexposed)** (n=8)

Harvesting	Soil		Plant Root		Plant Stem		Plant Leaves	
period	Exposed	Un	Exposed	Un	Exposed	Un	Exposed	Un
1 month	3.21±0.15	nd	0.18±0.01	nd	0.22±0.01	nd	0.37±0.02	nd
2 months	1.96±0.08	nd	0.40±0.01	nd	0.50±0.03	nd	0.57±0.01	nd
3 months	1.58±0.09	nd	0.55±0.03	nd	0.61±0.03	nd	0.72±0.04	nd
4 months	1.42±0.07	nd	0.61±0.02	nd	0.70±0.04	nd	0.83±0.02	nd
5 months	1.16±0.08	nd	0.74±0.06	nd	0.82±0.05	nd	1.06±0.07	nd
6 months	0.71±0.05	nd	0.82±0.05	nd	0.91±0.04	nd	1.11±0.05	nd
$LSD_{0.05}$	-		0.076		0.23		0.15	

Values are means ± SD of eight replicates. The mean values of root, stem, and leaves were statistically analysed using one way analysis of variance (ANOVA). Since $F_{critical}$ (3.6823) > F (1.2179), this shows that the means are not significantly different at probability of 0.05 and df 17. The Fisher's LSD shows that at least one of the mean concentration from the root, stem and leaves is statistically different, the critical value is 2.1314. Parameters with nd means not detected
Un = unexposed

Table 6: Concentration of Cr in landfill exposed soil, unexpoesd soil and *P. fruticosa* parts **(exposed and unexposed)** (n=8)

Harvesting	Soil		Plant Root		Plant Stem		Plant Leaves	
period	Exposed	Un	Exposed	Un	Exposed	Un	Exposed	Un
1 month	3.13±0.14	nd	0.17±0.01	nd	0.23±0.01	nd	0.29±0.02	nd
2 months	1.56±0.06	nd	0.24±0.03	nd	0.36±0.01	nd	0.42±0.01	nd
3 months	1.21±0.08	nd	0.32±0.02	nd	0.52±0.04	nd	0.65±0.03	nd
4 months	0.95±0.02	nd	0.45±0.01	nd	0.74±0.03	nd	0.97±0.02	nd
5 months	0.63±0.04	nd	0.53±0.03	nd	1.01±0.08	nd	1.38±0.06	nd
6 months	0.46±0.02	nd	0.68±0.06	nd	1.12±0.07	nd	1.51±0.08	nd
$LSD_{0.05}$	-		0.817		0.459		0.358	

Values are means ± S.D. of eight replicates. The mean values of root, stem, and leaves were statistically analyzed using a one-way analysis of variance (ANOVA). Since $F_{critical}$ (3.6823) > F (2.4134), this shows that the means are not significantly different at the probability of 0.05 and df 17. The Fisher's L.S.D. shows that at least one of the mean concentration from the root, stem and leaves is statistically different, the critical value is 2.1314. Un = unexposed

DISCUSSION

Plant survival and biomass

The biomass value increases consistently with the increase in the harvesting period. It could be due to sufficient nutrients in the soil (Fitzsimons and Vallejos, 1986) or some other factors such as a period of growth, temperature, and solar radiation (Eid *et al*., 2019). The results showed that landfill soil might improve the growth of *P. fruticosa* and could affect the plant's bacterial community. And maybe the microbe's community possesses many plant growth-promoting bacteria species that may supply the plant growth regulators, protect it from soil disease, and supply more nitrogen (Fauziah *et al*., 2017). Furthermore, there was a significant increase in height, stem diameter, and dry biomass weight within the harvesting period (Table 2). Meanwhile, the concentration of heavy metals determined from plant parts was significant compared to the unexposed plant.

The concentration of heavy metals in plant parts

Arsenic level was found high in the leaves, with concentration ranged between 0.29– 0.76 mg/kg. The As accumulation in the exposed plant part followed the pattern, leaves > root > stem. Generally, some plant species have higher As concentration levels in the root compared to the aboveground part, for example, *Spartina pectinata* (Rofkar and Dwyer, 2013). While, some plant species, such as radish, have higher As concentration in the shoots than the roots (Smith *et al*., 2008).

The concentration of Cd in the root of exposed plant was found significantly high on six months harvesting period, as shown in Table 4, which could be deduced that the plant can uptake Cd from landfill soil. In the case of the stem and leaves of the exposed plant sample, Cd concentration levels on six months harvesting period were found to be 0.24 and 0.21 mg/kg respectively. As expected, cadmium was not detected in the stems and leaves of the exposed plant. The concentration of Cd accumulated in the plant root within the experimental period was higher (0.11 – 0.33 mg/kg) than stems and leaves. Therefore, it describes less transfer of Cd to aboveground parts, as shown in Table 4. Furthermore, Cd concentration in the exposed plants exceeds the (Environmental Quality Regulations 2009, Malaysia, (E.Q.R. 2009) allowable limit, as illustrated in Table 1. Cd sources could be ascribed to waste disposal that contains cement, non-ferrous metal, and steel on dumpsites. The environmental concern here is the discharge of hazardous heavy metals into the environment.

It was found that exposed plant leaves have the highest concentration of Pb, which ranged between 0.37 – 1.11 mg/kg; however, Pb was not detected from unexposed plant part. The concentration range of Pb accumulated in the root and stem was 0.18 – 0.82 mg/kg and 0.22 – 0.91 mg/kg, respectively, as presented in Table 5. Therefore, it could be concluded that the plant part has a concentration gradient above E.Q.A. standard allowable limits, which was 0.1 mg/kg for Pb. The concentration level of Pb in the plant parts indicates the level of waste disposal of lead batteries, plastics, lead-based paints, and pipes into the soil (Moturi *et al*., 2014). The absorption of Pb into the root depends on the binding of Pb to ion exchange sites on the cell wall.

A higher concentration of Cr range between 0.29 – 1.51 mg/kg was observed in the leaves of the exposed plant. The concentration level of Cr accumulated in plant part exceeds the standard limit proposed by E.Q.A. (2009) Table 1. The accumulation consistently increased from root to the leaf, showing a significant Cr transfer to the aboveground part. In a study carried out to investigate heavy metals collection in *P. vittata*, Cr was accumulated in the root and frond (the leaf or leaflike part of a plant) with concentrations 0.08 and 0.014 mg/kg, respectively (from site A) (Marbaninang *et al*., 2016). In another study, *Portulaca oleracea* accumulated 1000 mg/kg of Cr and made it a Cr hyperaccumulator plant (Alyazour *et al.,* 2014). Chromium is a micronutrient that helps in crop production and other agricultural practices such as livestock farming. But Cr was not detected from unexposed plant.

Statistical analysis of data

The least significant difference (L.S.D.) was used for multiple comparisons at $p < 0.05$ between the three plant parts (root, stem, and leaves). A probability (p-value) greater than 0.05 signifies that the means have no significant difference. A p-value of less than 0.05 shows a substantial difference between the mean. The mean concentration levels for six different harvesting periods of the selected heavy metals in the roots, stems, and leaves of *P. fruticosa* were compared for significant differences and presented on the respective heavy metals table. It was found that Cr and Pb were significantly higher in the leaves compared to stems and roots. There are no significant differences between the groups of roots, stem and leaves since the absolute values are less than the differences between the groups. The accumulation pattern of Cr and Pb in the plant parts was leaves > stem > root throughout the harvesting period. The results of Cd did not follow the same way. Instead, Cd was higher in the root, followed by the stem and the leaves. Arsenic has a different trend of accumulation in plant parts with concentration level; leaves > roots > stems the pattern of As accumulation and translocation were a little bit peculiar to that of Cr and Pb. Although Cr, Pb and As have high concentration level in the leaves, there are few significant differences in terms of accumulation capacity of these heavy metals at different harvesting periods, which shows that leaves of the plant were able to accumulate high concentration.

Percentage Removal

It was observed that the concentration level of Cd removed from the landfill soil by *P. fruticosa* within the experimental period was higher compared to other selected heavy metals, as shown in Figure 1. At the same time, the low percentage removal occurred on Pb with a value of 77.88%. Furthermore, it was reported in a similar experiment that sunflower reduces the concentration of Cd and Pb with 100 and 55.8% percentage removal, respectively (Martins *et al.*, 2014). Thus, the results for the tested plant confirmed that *P. fruticosa* could be used in the phytoremediation of heavy metals from landfill soil.

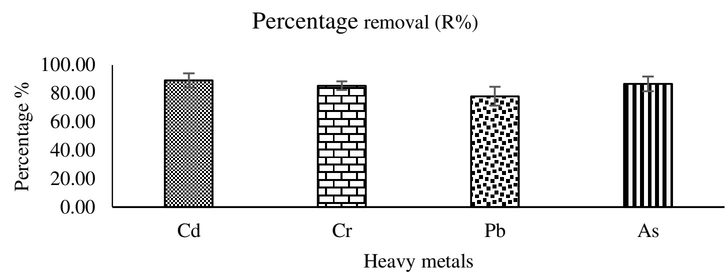

Figure 1: Removal of Cd, Cr, Pb, and As by the *P. fruticosa* plant from landfill soil. Values are the means and standard deviation of three replicates.

Bioconcentration, Translocation factors and Extraction coefficient

The efficiency of plants to accumulate heavy metals is measured by a bio-concentration factor (BCF) A high quantity of heavy metals in the plant's parts indicates the high capability of the plant to accumulate heavy metals. The maximum BCF value occurred for Cd and As on the 6th month harvesting period. The BCF values increased by following the trend 1< 2 < 3 < 4 < 5< 6 months harvesting period. The translocation factor was determined and presented in Figure 2. In this study, *P. fruticosa* can be applied in the removal or reduction of heavy metals. Furthermore, it was indicated that the variations in some TF in different plant parts might be attributed to the differences in the type and concentration of heavy metals present in the soil and differences in heavy metals uptake capability of the plant (Zheng *et al.*, 2007). An efficient translocation of Cd was observed from the root to the leaf part with a TF value > 1. A significant Pb and As were translocated to the aboveground part with a TF value two-fold > 1. Arsenic translocation from stem to leaves was higher compared to translocation from root to stem. The TF values of As, Cr, and Pb indicate a good mobility capacity towards the plant's aboveground parts. It was noticed that the presence and toxicity of heavy metals in this landfill soil do not affect the plant's ability to translocate As from roots to its stem and leaves. The TF values of As were two times > 1, which indicates an effective transfer of As in the mixture of other heavy metals. The phytoremediation efficiency of *P. fruticosa* was determined by As accumulation of its aboveground parts. The variations in TF values among the targeted heavy metals could be due to heavy metal's situations (Yang *et al.,* 2010). These situations could affect the potential of heavy metals extraction and change their translocation within the plant parts (Weis *et al.*, 2004). The EC threshold of >1 was obtained on 3 - 6 harvesting periods by Cd and Cr, while EC value > one was obtained on 2 – 6 harvesting periods by Pb. Arsenic shows an EC value > 1 on 4 – 6 harvesting periods. This study shows that the phytoextraction coefficient depends on the type and combination of heavy metals (Zaefarian *et al.*, 2012).

CONCLUSION

Based on the results obtained from this study, it can conclude that phytoremediation is a promising remediation option for landfill soil. *P. fruticosa* analysed for its potential to survive and grow on landfill soil. The plant could extract and accumulate heavy metals in the root and transfer them to the leaf during the study. The plant height, diameter, root, and shoot length increased consistently with the increase in the harvesting period. High percentage removal occurred for Cd followed by As, then Cr and Pb. It indicates that this plant is a good tolerant to the abandoned landfill soil. Therefore, based on the results obtained from the study, *P. fruticosa* can reduce the concentration of heavy metals from landfill soil. Different methods should be applied to the same plant species to investigate and determine their optimum suitability in treating landfill soil. Field studies with this plant should be employed

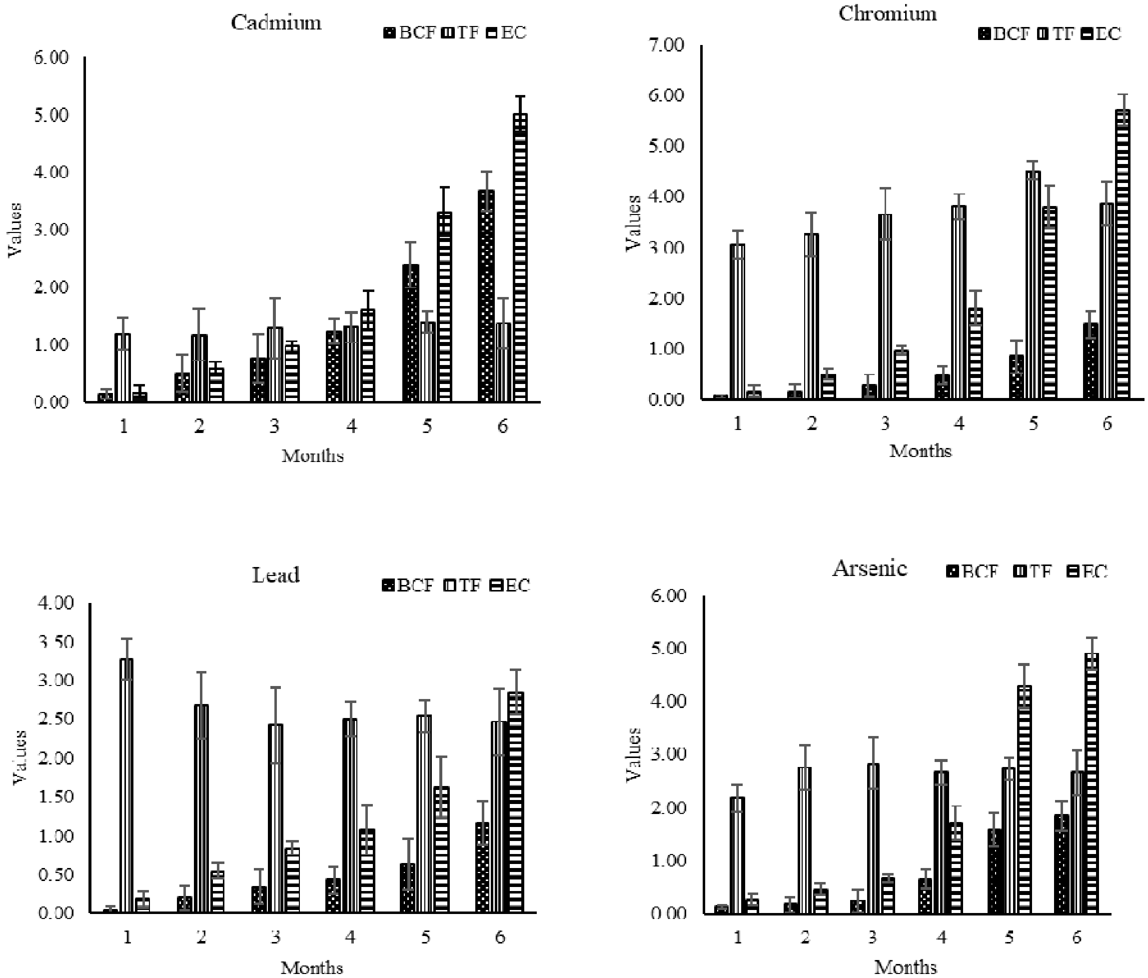

Figure 2: Means and standard deviation (n = 3) of bioconcentration factor, translocation factor and extraction coefficient of Cd, Cr, Pb and As on six different harvesting period. The BCF of Cr, Pb and As were lower compared to the values of TF and EC, while in the case of Cd, BCF was higher than TF on the 5th and 6th harvesting period. TF values of the heavy metals were more significant than one throughout the harvesting period.

Conflict of interest

We declare that there is no conflict of interest.

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