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PHYTOREMEDIATION POTENTIAL OF ELEMENTS BY WEED SPECIES AROUND SOLID WASTE DUMPING GROUND, BERHAMPUR, WEST BENGAL, INDIA

SUDIPTA BISWAS[1]*, SOUMENDRA NATH TALAPATRA[2] AND PHANI BHUSAN GHOSH[1]

[1]*Department of Chemistry,*
[2]*Department of Bio-Science,*
Seacom Skills University, Kendradangal, Shantiniketan,
Birbhum 731 236, West Bengal, India

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ABSTRACT

Phytoremediation capability of weed species (*Lantana camara* and *Sida* sp.) for heavy elements like lead(Pb), cadmium (Cd), and arseni c(As) in the soil around the solid waste dumping site was assessed. This study revealed that the average level (mg/kg) of occurrence of these elements in surface soil followed the order of Pb (51.89) > As (6.25) > Cd (2.45), below the prescribed level of Indian standards. Similar pattern of elemental distributions was also recorded in cases of soil humus, sub-soil and various weed segments like root, stem, and leaf. Leaf components of these species could be used As bio-indicator as well as phytoextractor for studied toxic elements. The bio-concentration soil factors (BCSF) were <1 and TF values were >1, indicating efficient transfer of these elements from root to leaf. Negative percentage values of re-translocation (RT) factor were observed signifying that *Sida* sp. excreted more Pb and Cd through senescent leaves while *L. camara* excreted more As than *Sida* sp. to the surface soil. Hence, both the species demonstrated higher capacity to accumulate Pb and Cd into the leaves as hyper-accumulator and could be efficiently used for phyto-remediation for these toxic elements from the soil.

KEYWORDS: Bioconcentration, Elements, Solid wastes, Phytoremediation, Weeds

INTRODUCTION

The municipal solid wastes (MSW) consisting of vegetable wastes, food wastes, garden wastes, papers, woods, plastics, construction and demolition wastes, glass, ceramics, electrical and electronic wastes, etc. are generated in urban area (Kolkata Municipal Corporation, 2010). Among these, few are biodegradables, but majority wastes are non-biodegradable. The designated landfill is used as the principal place for solid waste dumping, which could cause potential source of environmental pollution (Esakku *et al.*, 2003; Giusti, 2009). The leachate runoff from open dumping sites showed dominant source of heavy metals in the surface water and underground source, soil, and plants (Slack *et al.*, 2005; Öman and Junestedt, 2008; Bakis and Tuncan, 2011; Long *et al.*, 2011; Kanmani and Gandhimathi, 2013; Van Ryan Kristopher and Parilla, 2014; Vodyanitskii, 2016; Gworek *et al*., 2016; Samadder *et al*., 2017; Yukalang *et al*., 2017; Vongdala *et al*., 2019).

Some of the heavy metals like Cu, Zn, Fe, Mo, Ni, etc. act as micronutrients in the biotic life. Other groups of metals like Pb, Cd, Hg, and metalloid As have no biochemical role at all, these are introduced in the organisms during uptake of nutritional elements and show harmful effect. All these heavy metals ultimately may contaminate the food resources through the food chain that could cause undesirable effect to the ultimate consumers to human beings. Large numbers of investigations regarding this aspect have been carried out especially in and near the solid wastes dumping sites (Esakku *et al*., 2005; Beyene and Banerjee, 2011; Demie and Degefa, 2015; Mouhoun-Chouaki *et al*., 2019). Sometimes, it was also observed that soil is contaminated due to unsafe disposal of large quantity of arsenic contaminated sludge, which is generated from arsenic removal water treatment plant (Mandal *et al*., 2016) and arsenic adsorbed candles after the removal of arsenic in water.

Till date, there are several technologies, which have been implied for MSW treatment and proper management for the prevention of soil and water pollution. These include physico-chemical treatment, thermal treatment, and bioremediation by using microbes (González-Martínez *et al*., 2019) but most of these facilities may have cost involvement, long duration, etc. (Volke and Velasco, 2002; González-Martínez *et al.,* 2019).

Now-a-days, phytoremediation is considered as the most promising technique and has been adopted in almost everywhere in the globe. Besides, it has also been reported nationally and internationally that some weeds are also able to extract the heavy metals from the soil and could remediate easily from the medium both *in situ* as well as *ex situ* conditions (Antonsiewicz *et al*., 2008; Wei *et al*., 2009; D'Souza *et al.,* 2010; Gurijala and Jasti, 2014; Girdhar *et al.,* 2014; Ogunkunle *et al.,* 2014; Anarado *et al.,* 2018; Fu *et al.,* 2019; Natasha *et al.,* 2020). According to Shahid *et al*. (2011), metals or metalloid have tendency to accumulate and translocated to roots and aerial parts viz. stem, leaves, etc. of plant species. It was reported that root is the main target to accumulate but it translocated to the different parts of the shoot of plant species (Al-Jobori and Kadhim, 2019). At the same time, little information is there regarding the status of heavy metals level in the soil around solid waste dumping ground of Berhampur Municipality, West Bengal, India.

In the light of the above facts, present study is an attempt to assess i) the extent of heavy metal contamination such as lead, cadmium, and arsenic in soil; ii) the degree of bioaccumulation of these toxic elements in root, stem and leaf by weed species grown extensively in this waste dumping area; and finally iii) the phytoremediation capability of these species in situ condition for toxic elements on the basis of bio-concentration soil factor (BCSF), translocation factors (TF) and % of re-translocation factor (RTF).

MATERIALS AND METHODS

Selection of study sites and weeds

The study sites were selected around the solid wastes dumping ground of Berhampur Municipality, West Bengal, India. The selection of study sites especially in west and east sides (core area) as well as north side as buffer area (Latitude = 24°07' N and Longitude = 88°32' E) during pre-monsoon period. The weed species such as *Lantana camara* and *Sida* sp. were selected as per availability in the study area.

Selection of heavy metals and metalloid

Two heavy metals viz. Pb and Cd and one metalloid as As were estimated in different layers of soils and different parts of the weeds.

Sample collection and analysis

Soil samples were collected from different layers such as humus, surface soil and 6cm depth soil and different parts viz. leaf, stem and leaf for each weed were separately collected from above-mentioned study area and sun-dried samples were kept in ziplock plastic packet with proper coding. For each sample, the digestion was done in concentrated nitric acid as per the protocol of Goldberg *et al.* (1993) and the elements viz. Pb, Cd, and As were estimated separately by using atomic absorption spectrophotometer (AAS model: Agilent Technology 200 Series AA).

Assessment of bioconcentration and translocation factor

The bioconcentration soil factor (BCSF) was determined by using established formula for each part of the weed specimen versus soil content for each metal and metalloid (McGrath and Zhao, 2003; Shingadgaon and Chavan, 2019). The formula is as follows:

Bioconcentration soil factor (BCAF) = metal concentrationin plant tissues (ppm dry weight) ÷ metal concentration insoil (ppm dry weight) ... (1)

The translocation factor (TF) for each weed was estimated by using established formula for metals or metalloid content in leaf divided by content in root and content in stem divided by content in root (Rezvani and Zaefarian, 2011; Kaewtubtim *et al*., 2016). According to them, when TF value >1 then it is known about weed's potential regarding translocation of metals or metalloid effectively from root to leaf and root to stem. The formula is as follows:

Translocation factor of leaf (TF_{leaf}) = Content in leaf ÷ Content in root .. (2)

Translocation factor of stem (TF_{stem}) = Content in stem ÷ Content in root .. (3)

Assessment of re-translocation factor

The re-translocation (RT) factor (%) was determined metals or metalloid absorption between senescent leaves (soil humus) and green leaves of the weed species as per the methods of Maldonado-Román *et al.* (2016). The formula is as follows:

Re-translocation (RT) factor = 1 –Metal or metalloid content in senescent leaf ÷ Metal or metalloid content in humus soil .. (4)

Statistical analysis

All statistical analyses such as correlation analysis and cluster analysis to detect relationships between the elements and accumulationin plant parts were performed by using statistical software, PAST (PAleontological STatistics version 3.26) developed by Hammer *et al.* (2001).

RESULTS

Fig. 1 explains the elemental content in different layers viz. humus, surface and 6cm depth of soil. For Pb content (mg/Kg), the mean ± standard deviation of about 53.09 ± 5.6 in humus, 51.82 ± 8.9 in surface soil and 59.8 ± 26.9 were obtained. For Cd content (mg/Kg), the mean ± standard deviation of about 2.48 ± 0.7 in humus, 2.45 ± 0.8 in surface soil and 2.6 ± 0.6 were obtained. For As content (mg/Kg), the mean ± standard deviation of about 6.91 ± 1.2 in humus, 6.25 ± 1.3 in surface soil and 6.8 ± 0.6 were obtained.

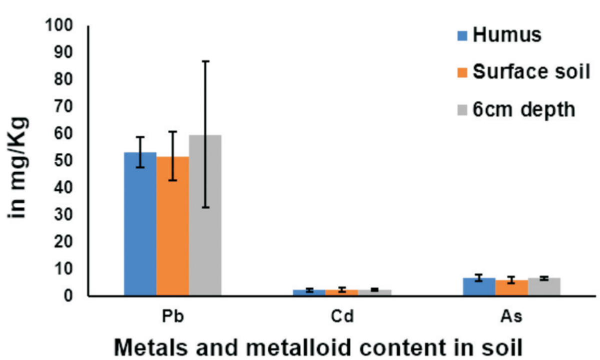

Fig. 1. Elemental content different layers of soil around solid wastes dumping ground

Fig. 2 exhibits the accumulation of elements in different parts viz. leaves, stems, and roots of weed (*Lantana camara*) located around the dumping ground. For Pb content (mg/kg), the mean ± standard deviation of about 8.50 ± 2.9 in leaves, 2.82 ± 1.7 in stems and 2.4 ± 1.2 were recorded. For Cd content (mg/Kg), the mean ± standard deviation of about 0.97 ± 0.4 in leaves, 0.50 ± 0.1 in stems and 0.6 ± 0.3 were recorded. For As content (mg/Kg), the mean ± standard deviation of about 2.22 ± 0.2 in leaves, 2.21 ± 1.2 in stems and 1.0 ± 0.3 were recorded.

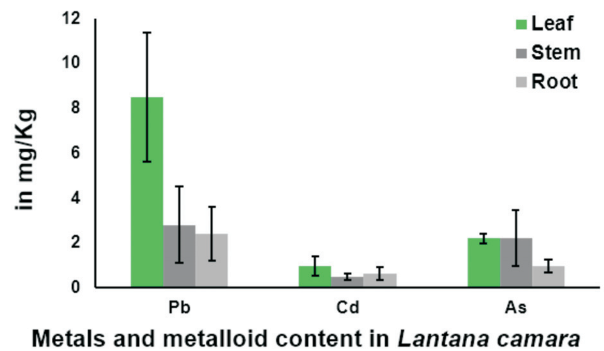

Fig. 2. Elemental accumulation in different parts of *Lantana camara*

Fig 3 describes the accumulation of elements in different parts viz. leaves, stems, and roots of weed (*Sida* sp.) located around the dumping ground. For Pb content (mg/Kg), the mean ± standard deviation of about 30.76 ± 17.6 in leaves, 13.52 ± 0.8 in stems and 17.4 ± 2.2 were recorded. For Cd content (mg/Kg), the mean ± standard deviation of about 1.54 ± 1.0 in leaves, 0.16 ± 0.1 in stems and 0.6 ± 0.4 were recorded. For As content (mg/Kg), the mean ± standard deviation of about 0.85 ± 0.4 in leaves, 0.46 ± 0.2 in stems and 1.1 ± 0.3 were recorded.

In Table 1, bioaccumulation soil factor (BASF) was obtained higher value of 0.71 and 0.56 in the leaf of *Sida* sp. for Cd and Pb followed by 0.44 and 0.34 in the leaf of *Lantana camara* for Cd and As. Comparatively higher value of about 0.34 was

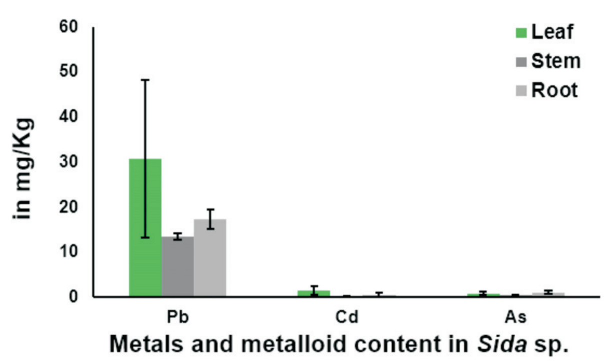

Fig. 3. Elemental accumulation in different parts of *Sida* sp.

obtained in the stem of *L. camara* for As and higher value of about 0.31 in the root of for Pb followed by 0.27 in the roots of *L. camara* and *Sida* sp. for Cd. Herein, all the values were <1 for BASF. In case of translocation factor (TF), Pb was highly translocated in leaf (3.54) and stem (1.17) of *L. camara* but only in leaf (1.72) of *Sida* sp.while Cd was highly translocated in leaf (1.62 and 2.57) of both weed species but, As was highly translocated in the leaf of *L. camara* as values were found >1 (Table 1).

In Fig 4, for these metals and metalloid, both the

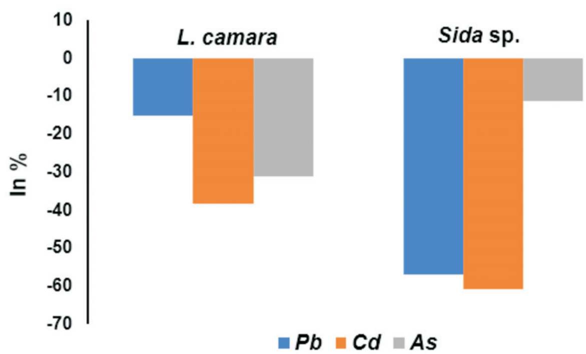

Fig. 4. RT (%) factors of elements by studied weeds

weeds were observed negative RT factor (%). The specimen *Sida* sp. was obtained higher negative value for Cd (-60.89) followed by Pb (-56.94) compared to *L. camara* for Cd (-38.11) and Pb (-15.01) while *L. camara* showed higher negative value (-31.15) compared to *Sida* sp. (-11.35) for As, respectively.

The correlation matrix results between the different parts viz. leaves, stems, and roots and elements accumulation are tabulated in Table 2. In case of the roots of *L. camara*, Cd is significantly ($P<0.05$) positively correlated with As (0.8709). For the weed (*Sida* sp.), in leaves, Pb is significantly ($P<0.05$) positively correlated with Cd (0.9875). In stems, Pb is significantly ($P<0.05$) positively correlated with Cd (0.9649), and as (0.8929) while Cd is significantly ($P<0.05$) positively correlated with As (0.9458). In roots, Pb is significantly ($P<0.05$) positively correlated with Cd (0.9236).

Cluster analysis was used by Ward's method to find the relationship between elements uptake and accumulation in the different parts of the studied weeds. The representation of dendrogram is exhibited in Fig. 4 (A-C). In Fig. 4 (A), cluster

Table 1. Elemental bioaccumulation soil factor and translocation factor of studied weeds

Plant species	Plant parts	BASF		
		Pb	Cd	As
Lantana camara	Leaf/soil	0.15	0.44	0.34
	Stem/soil	0.05	0.23	0.34
	Root/soil	0.04	0.27	0.15
Sida sp.	Leaf/soil	0.56	0.71	0.13
	Stem/soil	0.24	0.07	0.07
	Root/soil	0.31	0.27	0.17
		TF		
Lantana camara	Leaf/root	3.54	1.62	2.22
	Stem/root	1.17	0.83	2.21
Sida sp.	Leaf/root	1.72	2.57	0.77
	Stem/root	0.75	0.27	0.42

Table 2. Correlation matrix between elements and different plant parts of weeds

Elements	Leaves			Stems			Roots		
				Lantana camara					
	Pb	Cd	As	Pb	Cd	As	Pb	Cd	As
Pb	1			1			1		
Cd	-0.8083	1		-0.6105	1		-0.6499	1	
As	-0.1856	-0.3011	1	0.0080	-0.0475	1	-0.2686	0.8709*	1
	Sida sp.								
Pb	1			1			1		
Cd	0.9875*	1		0.9649*	1		0.9236*	1	
As	0.3237	0.22452	1	0.8929*	0.9458*	1	-0.2911	-0.2968	1

Significant correlation at *$P<0.05$

analysis was performed for the leaves in which alarge portion of Pb in *L. camara* and *Sida* sp. formed a small group of clusters while small portion of Pb of *L. camara* and large portion of Cd, and as of these two weeds formed large groups of cluster, but a large distance of 40 obtained in the case of Pb in *Sida* sp. in comparison with other groups of elements in leaves. In Fig 4 (B), cluster analysis was performed for the stems in which small portion of Pb in *L. Camara* and large portion of As and Cd observed in these two weeds formed large group of clusters, but a large distance of 15 obtained in the case of Pb in

Fig. 4. Dendrogram of cluster analysis for elemental accumulation in leaves (A), stems (B) and roots (C) of studied weeds based on Ward's method algorithm (L = *Lantana camara*; S = *Sida* sp.)

Sida sp. in comparison with other groups of elements in stems. In Fig 4 (C), cluster analysis was performed for the roots in which the large portion of Pb in *L. camara* and *Sida* sp. formed a small group of clusters while small portion of Pb of *L. camara* and large portion of Cd and As in these two weeds formed large groups of cluster, but a large distance of 10 obtained in the case of Pb in *L. camara* in comparison with other groups of elements in roots. As a result, the Pb did not correlate with other elements like Cd and As during accumulation in the leaves and stems of *Sida* sp. while the Pb did not show correlation with other elements like Cd and As during accumulation in the roots of *L. camara*.

DISCUSSION

In the present study, different layers of soils obtained increased (5-fold) level of Pb content, and it was exceeded that limit value of 10 mg/kg mentioned by Sharma *et al*. (2018) and Gebeyehu and Bayissa (2020) but too much lower value of the Indian Standard of 250-500 mg/Kg (ISI, 1983; Awashthi, 2000). Cd levels in all the segments were recorded lower than the limit of Indian Standard (ISI, 1983; Awashthi, 2000) and As also registered within the limits as per the citation of Brown (1987). In earlier study, the Pb, Cd, and As content were reported less in value (86.0 ±16.0, 1.29±0.31 and 0.57±0.38 mg/Kg, respectively) in soil around MSW dumping ground in other parts of southern India (Esakku *et al.*, 2005).

It was established that plants can potentially accumulate heavy metals or metalloid from the surrounding environment with the higher value (Yoon *et al*. 2006; Fu *et al*., 2019). As per phytoremediation ability, these two species are well-known regarding metal uptake capacity (Waoo *et al*., 2014; Anarado *et al*., 2016). According to Waoo *et al.* (2014), the Pb and Cd accumulated of about 262.2 and 49.4 mg/Kg and 88.4 and 28.76 mg/Kg in the leaves and shoots, respectively by *L. camara*. Anarado *et al.* (2016) reported in the *ex situ* study the higher accumulation level(0.713, 1.108, and 1.223 mg/Kg) of Pb in leaves, stem and root, respectively and 4.932, 5.241 and 6.495 mg/Kg of Cd in leaves, stem and root, respectively by *Sida* acuta. These values were different from the present study that could be due to pot culture. In the present study, the As content was lower values in the plant parts like leaves, stems and roots of both the weeds compared to earlier study of Fu *et al.* (2019). It is stated that heavy metal accumulation depends on elements activity and physiology of the species that may emphasize the phytoremediation abilityto a great extent (Yoon *et al.,* 2006; Zacarías *et al*., 2012; Fu *et al*., 2019).

When the BASF value is <1 then it is unable to phyto extract the elements (Fitz and Wenzel, 2002; Fu *et al.*, 2019).Present results showed all the values were <1 for leaves, stems, and roots of both the weeds. But as per TF, it was found both species could be recognized as hyper accumulator for Pb and Cd while *L. camara* was only observed as As hyper accumulator but *Sida* sp. behaved like excluder for As metalloid. An earlier *ex-situ* study indicated that increased concentration of Pb in soil decreased the value of TF in leaves followed by stem (Al-Jobori and Kadhim, 2019), which is contradicted with the present findings may be due to species specificity. For Cd, TF value was recorded highest in the leaf followed by stem for both weeds that might be due to hyperaccumulation capacity of the species, which is *Impatiens glandulifera* (Coakley *et al*., 2019). In case of As, *Pteris vittata* are illustrated for effective uptake and translocation efficiency in the shoot (fronds) as per TF (Su *et al.*, 2008), which has similarity with the present results. An earlier study by Cunningham *et al*. (1997) suggested that good hyperaccumulators can accumulate 1-3% Pb ions in leaves and stems, which is supported for the Pb accumulation in the present study.

It has been reported that the determination of RT (%) factor is an important determinant, which assesses the extent of element re-translocation by the plant to the soil (Mejías *et al.*, 2013). The negative values could signify the elemental excretion is more through the leaf fall (Maldonado-Román *et al*., 2016). The present findings showed that *Sida* sp. excreted more Pb and Cd and *L. camara* recycled more As through the leaf fall to the surface soil.

In general, strong positive correlations between the components are used to infer common sources or similar behaviour or synergic interactions and negative values results due to contribution from various sources or different behaviour or antagonistic relationships. In the present study correlation matrix revealed that the accumulation of Pb and Cd in all parts of the species *L. camara* could be regulated either for similar absorption mechanism or for similar sources. The Cd accumulation in stem might be different in nature. *L. camara* have significantly positive correlation between Cd and As while the leaves and stems of same weed have significantly positive correlation between Pb and Cd, Cd and As and in the case of another weed (*Sida* sp.), the leaves between Pb and Cd, stems between Pb and Cd along with As and roots between Pb and Cd observed good correlation, which is indicated that eachmet almayberes ponsible to accumulation of other metals or metalloid (Fu *et al.*, 2019). Furthermore, the multi variable cluster analysis indicated that the character of heavy metals or metalloid accumulated between species (Yu *et al.*, 2012) and the optimal number of clusters indicated that each part of weed classied into four clusters, while the studied metals and metalloid were grouped as per their concentrations (Nazzal *et al.*, 2021).

CONCLUSION

In the present study, two weed species inhabited in the solid waste dumping ground were selected during pre-monsoon season for accumulation of heavy metals viz. Pb and Cd and one metalloid As to determine the phyto remediation capability. A comparison of heavy metals and metalloid accumulation potential between these species from soil was donė. Both the species were observed higher capacity to accumulate Pb and Cd into the leaves as hyperaccumulator and *Sida* sp. is excluder for As metalloid as per BCF and TF values. The accumulated metals and metalloid in the leaf of the weeds could be collected and separately treated by incineration so that the generated metals and metalloid could be used. Future study is urgently needed to have the knowledge of phytoremediation ability of other weeds growing in this area for an identification of the more efficient species in the region.

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Conflict of interest

No conflict of interest is mentioned by the authors.

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