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Phytoremediation Potentiality of Lead from Contaminated Soils by Fibrous Crop Varieties

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Abstract: Lead (Pb) is one of the most toxic heavy metal in soils causing toxicity to human and biota. Phytoremediation of Pb contaminated soils by different fibrous crop varieties like jute (*Corchorus capsularis* L. cv. BJC-7370 & CVE-3), kenaf (*Hibiscus cannabinus* L. cv. HC-95 & HC-3) and mesta (*Hibiscus sabdariffa* L. cv. Samu-93) were investigated in this study. All varieties accumulated considerable amounts of Pb. The concentrations and uptake of total Pb by shoot were higher than root and significantly varied from variety to variety. Kenaf and mesta varieties took off more Pb than jute varieties from contaminated soils. Higher was the contents of Pb in soil higher was the accumulation and vice - versa. Highest amount of Pb (422.73 mg pot^{-1}) was uptake by the shoot of kenaf HC-95 followed by kenaf HC-3 (378.19 mg pot^{-1}) and jute BJC-7370 (3.51 mg pot^{-1}) from Pb contaminated soil. In terms Pb accumulation, kenaf varieties HC-3 and HC-95 showed higher phytoremediation potentiality of Pb from contaminated soil. Since these plants are primarily considered for fiber crops in addition to making paper pulp, construction materials, biofuel and firing/burning purposes therefore, there is a little chance for secondary contamination and minimize the drawbacks of phytoremediation technology.

Keywords: Environment, Fibrous Crops, Lead, Phytoremediation, Pollution, Soil

1. Introduction

Pb is a toxic element listed as the hazardous substances by The U.S Agency for Toxic Substances and Disease Registry (ATSDR, 2008) and has potential threats for human health and the environment, through their accumulation in the soil, water and, in the food-chain. Soil pollution by Pb contamination is a matter of concern in all over the world. Pb bearing rocks, minerals and anthropogenic activities are the main sources of Pb in the environment. The amount of Pb released in the environment is comparatively more than natural release. About 333 times more amount of Pb released by human activities than natural release (Khopkar, 2005). Inorganic and organic Pb has been disposed in the environment due to urbanization, industrialization and new technological development in different sectors. The principal sources of Pb in the environment are gasoline, plumbing, lead painting and ceramic painting used for cutlery etc (WHO, 2011). Leaded petroleum sold in the market as the ignition control additive and anti-knocking agent is a source of Pb. Other sources of Pb are ceramic utensil, glass components, and white pigments industry. Battery assembling units give out large amount of Pb in the effluents. However, whatever may be the source of releasing Pb, the ultimate destination of the heavy metal is in soil and water environment.

The arable soils of dense industrial area of *Bhaluka* upazila in Bangladesh contained Pb ranged form 42.52 - 90.93 mg

kg^{-1} and the concentration was decreased with the increase in distance of its source of origin (Zabir, 2014). In dry and wet season average Pb content of industrially polluted soils of Bangladesh was 130.29 and 95.08 mg kg^{-1}, respectively (Mondol *et al.*, 2011). The rice and vegetable soils of southern Jiangsu, China contained Pb ranged from 20.8 - 37.5 mg kg^{-1} and 18.7-152.7 mg kg^{-1} (Hongbin *et al.*, 2010). The soils of Jajmau and Unnao industrial areas of Uttar Pradesh, India significantly contaminated with Pb and concentration varied from 10.1 - 67.8 mg kg^{-1} (Gowd *et al.*, 2010). Average Cd and Pb concentrations in soils of Shenyang, China were 0.42 and 75.29 mg kg^{-1}, respectively (Sun *et al.*, 2010). Lead content of soils collected from the different locations near the pharmaceutical, textile, tannery, battery and food and beverage industries and pond, beel, river, hand tubewell, shallow tubewell and deep tubewell of Gazipur district ranged from 10-128 mg kg^{-1} (Begum, 2006); 12.0-34.0 mg kg^{-1} in soils of Bhaluka Upazila of Mymensingh district (Ahmed *et al.*, 2004); 34.3 -75.2 mg kg^{-1} in the street samples of very high traffic density area of Dhaka city of Bangladesh (Faruque *et al.*, 2007). The mean concentration of Pb (mg kg^{-1}) in calcareous soils was (22.80) and in non calcareous soil was 24.10 (Jahiruddin *et al.*, 2000).

Like other toxic metal Pb also entered into the body of organism through food chain and shows various adverse effect. The effect of lead poisoning is chronic. It can cause abdominal pain and wrist drop leading to mild attack of paralysis or stroke in human, which is similar to symptoms of cardiac disorders. In woman, it causes sterility while in man it weakens reproductive systems (Khopkar, 2005). Therefore, attempt should be taken to remediate Pb from contaminated site by means of eco-friendly approach.

Though Pb has adverse effect on plants but plants have wide range of Pb toxicity tolerance. Studies have shown that some plant species are potential to absorb toxic metals from the contaminated environment. Research also conducted to evaluate the effects of heavy metals on live plants (Raskin and Ensley, 2000). Dasguta *et al.* (2011) observed visible decrease in biomass production in *Cicer arietinum* (L.) due to the effect of Pb in contaminated soil. Bada and Kalejaiye (2010) observed that kenaf (*Hibiscus Cannabinus* L.) is highly potential for the phytoremediation of artificially Pb contaminated soil. Ho *et al.* (2008) explained that kenaf (*Hibiscus Cannabinus* L.) has potentiality to tolerate different concentrations (0,100, 200 & 400 mg Pb L^{-1}) of Pb and effective for phytoremediation of Pb contaminated site. The varieties of kenaf HC-3 and HC-95 and mesta Samu-93 easily germinate up to 100 mg L^{-1} of Pb contaminated medium and in all cases root and shoot growth of seedling was affected at high concentrations (Nizam *et al.*, 2013). Research work on the phytoremediation of Pb contaminated soil by jute, kenaf and mesta is very limited. In addition, these plants are extensively used as fibrous crops as well as production of paper pulp, biofuel, construction materials etc. (Dhar *et al.*, 2015), so the secondary or post harvest contamination of Pb will be limited which will be minimized the drawbacks of phytoremediation study. So the current study has been carried out to evaluate these fibrous crops for removal of Pb from contaminated soil environment and developed a sustainable and eco-friend phytoremediation technology.

2. Materials and Methods

2.1. Study Area, Soil and Plant Sampling

Lead contaminated soil was collected from the industrially polluted region of Bhaluka upazila in Bangladesh. Uncontaminated soil was also collected from the same series. The physical and chemical characteristics of soils have been presented in Table 1. In this study, soil containing Pb 69.74 mg Pb kg^{-1} considered as uncontaminated soil and 157.45 mg Pb kg^{-1} as Pb contaminated soil, since the threshold level of Pb for crop production is 100 mg kg^{-1} (Magyar, 2000). Exactly 10 kg processed and air-dried soil was taken in plastic pot (30 cm × 20 cm × 25 cm). Soils were moistened at 70% of the field capacity level with Pb free deionized water. Completely randomized design (CRD) with 4 replications was followed for experimentation. Uniform textured surface sterilized (by dipping 95% ethanol) seeds of kenaf (*Hibiscus cannabinus* L. cv. HC-95 & HC-3), mesta (*Hibiscus sabdariffa* L. cv. Samu-93) and jute (*Corchorus capsularis* L. cv. BJC-7370 & CVE-3) were used. Ten seeds of each variety were sown in each pot and thinned to 6 seedlings per pot a week after germination; the thinned seedlings were incorporated into the pot soil (Fig. 1). Nitrogen (N), phosphorus (P) and potassium (K) were applied as recommended by Islam and Rahman (2008). From sowing to harvest, the pots were kept under the shade of transparent polyethylene to protect rainwater. Weeding, irrigation with Pb free water and other necessary intercultural operations were done when needed. Plants were harvested at 120 DAS. At the time of harvest shoot and root samples of each variety were collected separately and cleaned thoroughly with tap water and rinsed with 0.1M HCl solution followed by several rinses with deionized water. Shoot and root samples were processed after oven dried at 75°C for 48 hours. Post harvest soil samples were collected separately from each pot.

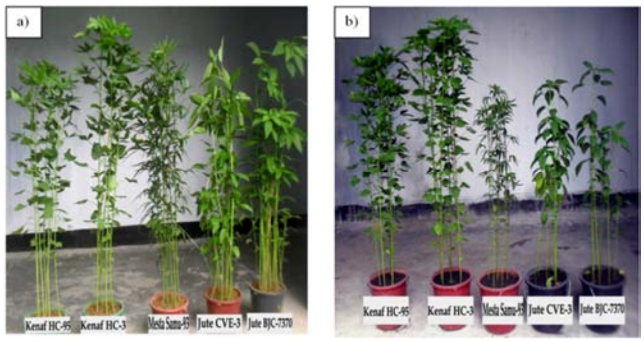

Fig. 1. *Kenaf, mesta and jute plants grown in- a) uncontaminated and b) contaminated soils.*

Table 1. *Characteristics of Pb contaminated and uncontaminated soils used for experiment.*

Characteristics	Pb Contaminated soil	Uncontaminated soil
A. Physical characteristics:		
Sand (%)	38	41
Silt (%)	34	30
Clay (%)	28	29
Textural class (USDA)	Clay loam	Clay loam
Particle density (g cm^{-3})	2.42	2.70
Bulk density (g cm^{-3})	1.32	1.68
B. Chemical characteristics:		
pH	6.65	6.50
Electrical Conductivity (µS cm^{-1})	460.00	101.00
Organic Carbon (%)	2.237	0.612
Organic Matter (%)	3.86	1.06
Total N (%)	0.60	0.0672
Available P (mg kg^{-1})	25.00	20.00
Available S (mg kg^{-1})	2250.00	10.00
Exchangeable K (mg kg^{-1})	235.00	12.65
Exchangeable Ca (mg kg^{-1})	10420.80	320.00
Exchangeable Mg (mg kg^{-1})	1166.64	155.00
Exchangeable Na (mg kg^{-1})	2086.96	63.56
HNO_3 Digestible Pb (mg kg^{-1})	157.45	69.74

2.2. Soil and Plant Analyses

Soil textures, bulk and particle densities were determined following method outlined by Klute (1986). pH and EC values of soil samples were measured electrometrically in a 1:2.5 and 1:5 suspension of soil and water, respectively (Tandon, 1995). Organic matter and organic carbon content of the soils were determined by wet oxidation method and total N were analysed by micro-kjeldahl method (Sparks, 1996). Available P and S were extracted with 0.5M $NaHCO_3$ and 0.15% $CaCl_2$ solution and the amount was determined by spectrophotometer at the wavelengths of 660 and 420 nm, respectively (Tandon, 1995). Soils were extracted with 1N NH_4OAc solution pH=7.0, for the determination of exchangeable K, Ca, Mg and Na. For the determination of Pb, soils were extracted following method outlined by Tam and Yao (1999). Oven dried plant samples were finely ground and digested with HNO_3 and H_2O_2 following procedure outlined by Cai *et al*. (2000). Pb, K, Ca, Mg and Na contents were determined from digested extract with the help of atomic absorption spectrophotometer (Model: Shimadzu AA 7000) at wavelengths of 283.3, 766.5, 422.7, 285.2 and 589.0 nm (Sparks, 1996). Standard reference materials and analytical grade reagents were used in all cases of analysis.

2.3. Bioconcentration Factor (BCF) and Translocation Factor (TF)

The BCF provides an index of the ability of the plant to accumulate the metal with respect to the metal concentration in the substrate. BCF or bioaccumulation factor (BAF) and TF of Pb were calculated following formulae outlined by Ho *et al.* (2008).

$BCF_{root} = C_{root}/C_{soil}$, where C_{root} is the concentration of element in root and C_{soil} is the concentration of element in soil.

$BCF_{shoot} = C_{shoot}/C_{soil}$, where C_{shoot} is the concentration of element in shoot and C_{soil} is the concentration of element in soil.

TF or mobilization ratio of a plant for a given metal is the ratio of the metal concentration in the plant parts in relation to the concentration of metal in the growth medium or ratio of the metal concentration in relation to one part to another part (i.e. from root to shoot).

TF (from root to shoot) = C_{shoot}/C_{root}, where C_{shoot} is the concentration of element in shoot and C_{root} is the concentration of element in root.

2.4. Statistical Analysis

Experimental data were analysis following method outlined by Gomez and Gomez (1984) and Duncan's multiple range tests (DMRT) were performed to verify the significance of difference. DMRT is commonly used in agricultural and other agronomic practices.

3. Results and Discussion

3.1. Biomass Production in Pb Contaminated and Uncontaminated Soils

As mentioned our earlier study Nizam *et al.* (2016) the plant varieties grown in experimental soils produced sufficient dry biomass of shoot and root that was varied from soil to soil and variety to variety (Table 2). In Pb contaminated soil, maximum dry biomass (589.39 g pot^{-1}) of shoot was measured in kenaf HC-3 followed by kenaf HC-95 (487.23 g pot^{-1}) and the lowest (17.20 g pot^{-1}) was in jute BJC-7370. On the other hand, the highest dry biomass (192.05 g pot^{-1}) of shoot was observed in uncontaminated soil in mesta Samu-93 followed by kenaf HC-3 (171.82 g pot^{-1}) and the lowest (104.75 g pot^{-1}) was in kenaf HC-95 (Table 2).

Table 2. *Dry biomass of shoot and root of jute, kenaf and mesta grown in Pb contaminated and uncontaminated soils.*

Variety	Shoot (g pot^{-1})		Root (g pot^{-1})	
	PbCS	UCS	PbCS	UCS
Jute BJC-7370	17.20d	169.42b	6.59d	36.52b
Jute CVE-3	42.51d	159.47b	6.63d	42.91a
Kenaf HC-95	487.23b	104.75c	121.93b	37.75b
Kenaf HC-3	589.39a	171.82b	133.70a	40.90a
Mesta Samu-93	168.15c	192.05a	31.02c	31.84c
Max	589.39	192.05	133.70	42.91
Min	17.20	104.75	6.59	31.84
Mean	260.90	159.50	59.97	37.98
SE±	63.00	8.19	15.04	1.07
LSD	31.60	11.41	3.38	1.59
Sig. levels	**	**	**	**

Legends: PbCS=Pb contaminated soil, UCS=Uncontaminated soil, ** = Significant at 1% level of probability. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

In Pb contaminated soil, maximum (133.70 g pot^{-1}) dry biomass of root was measured in kenaf HC-3 followed by kenaf HC-95 (121.93 g pot^{-1}) and the lowest (6.59 g pot^{-1}) was in jute BJC-7370. On the other hand, the highest (42.92 g pot^{-1}) dry biomass of root was detected in uncontaminated soil in jute CVE-3 followed by kenaf HC-3 (40.90 g pot^{-1}) and the lowest (31.84 g pot^{-1}) in mesta Samu-93.

3.2. Pb content in Shoot and Root of Jute, Kenaf and Mesta Grown in Pb Contaminated Soil

Biomass production and uptake capacity of a plant species is very important for phytoremediation. Pb concentrations were higher in shoot and root grown in Pb contaminated soil than uncontaminated soil (Fig. 2). In contaminated soil, the highest Pb content of shoot (867.55 mg kg^{-1}) was determined in kenaf HC-95 followed by kenaf HC-3 (642.22 mg kg^{-1}) and the lowest was in jute BJC-7370 (203.65 mg kg^{-1}). For uncontaminated soil, maximum Pb concentration in shoot was 264.48 mg kg^{-1} in kenaf HC-3 followed by mesta Samu-93 (244.96 mg kg^{-1}) and the lowest (137.60 mg kg^{-1}) was in jute BJC-7370 (Fig. 2). For contaminated soil the highest concentration of Pb in root (329.66 mg kg^{-1}) was detected in kenaf HC-95 followed by jute CVE-3 (298.38 mg kg^{-1}) and the lowest (171.52 mg kg^{-1}) was in mesta Samu-93. Nevertheless, in uncontaminated soil the maximum Pb concentration (191.68 mg kg^{-1}) for jute CVE-3 followed by jute BJC-7370 (144.47 mg kg^{-1}) and the lowest (134.81 mg kg^{-1}) was measured from the variety of kenaf HC-3 (Fig. 2).

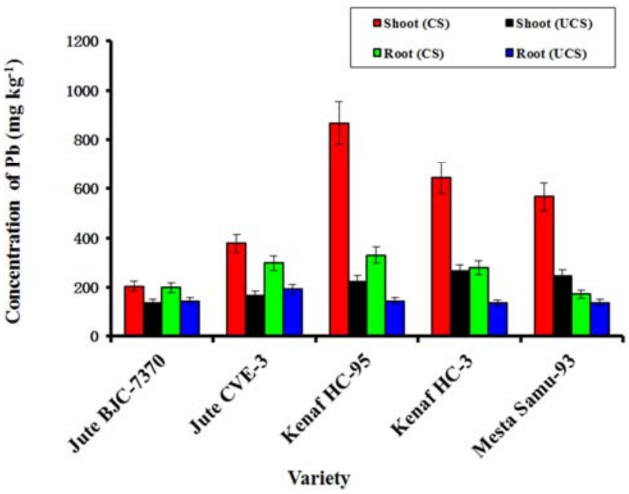

Fig. 2. *Pb content pattern in shoot and root of jute, kenaf and mesta grown in contaminated and uncontaminated soils. Error bars indicate Mean±SE.*

Most of the varieties grown in Pb contaminated soil accumulated more Pb in shoots than roots indicated that in Pb contaminated soil Pb was easily transported from root to shoot and it might be due to the higher Pb content and that was connected with other essential ions during nutrient uptake. The variations of Pb contents in shoots and roots of jute, kenaf and mesta plants depending upon the chemical characteristics of the soils. The present findings were correlated with the findings of Bada and Kalejaiye (2010), they obtained varying amounts (5.26-78.17 mg Pb kg^{-1}) of Pb absorption by kenaf grown in different concentrations (0, 150, 300, 450 and 600 mg Pb kg^{-1}) of applied Pb in soil.

3.3. Pb Uptake by Shoot and Root in a Pot

Pb uptake by shoot and root significantly varied from variety to variety and soil to soil (Table 3). In Pb contaminated soil, the highest amount of Pb (422.73 mg pot^{-1}) was uptake by the shoot of kenaf HC-95 followed by kenaf HC-3 and jute BJC-7370 (Table 3). In case of root in the Pb contaminated soil, the highest amount of Pb (40.23 mg pot^{-1}) was also accumulated by the root of kenaf HC-95 followed by kenaf HC-3 (37.35 mg pot^{-1}) and the lowest (1.31 mg pot^{-1}) by jute BJC-7370. For uncontaminated soil, maximum quantity of Pb (8.22 mg pot^{-1}) was absorbed by root of jute CVE-3 followed by kenaf HC-3 (5.51 mg pot^{-1}) and the lowest (4.38 mg pot^{-1}) was absorbed by mesta Samu-93 (Table 3).

Higher amount of Pb took off by shoot and root of plants in Pb contaminated soil than that of uncontaminated soil indicated that, the more the Pb contents in the soil more was the absorption of Pb by plant parts. Bada and Kalejaiye (2010) also observed that the higher the concentrations (at the levels of 0, 150, 300,450 and 600 mg Pb kg^{-1}) of Pb applied, the more were Pb absorption in kenaf in the two soils (UNAAB and Epe soils). For all the varieties, the above ground plant parts (shoots) uptake higher amount of Pb than below ground plant parts (roots). Islam *et al.*, (2015) also found that *Micranthemum umbrosum* can uptake higher amount of arsenic in leaf and stem then root. From the results of Pb uptake by above ground plant parts, it is very clear that the varieties were able to remediate significant amount of Pb from contaminated soils. In Pb contaminated soil, the Pb remediation potentiality of the varieties were kenaf HC-3 > kenaf HC-95 > mesta Samu-93 > jute CVE-3 > jute BJC-7370 (Table3).

Table 3. *Pb uptake by shoot and root of different varieties of jute, kenaf and mesta grown in contaminated and uncontaminated soils.*

Plant variety	Shoot (mg pot^{-1})		Root (mg pot^{-1})	
	PbCS	UCS	PbCS	UCS
Jute BJC-7370	3.51d	23.28d	1.31d	5.28b
Jute CVE-3	16.03d	31.87c	1.97d	8.22a
Kenaf HC-95	422.73a	23.41d	40.23a	5.44b
Kenaf HC-3	378.19b	45.41b	37.35b	5.51b
Mesta Samu-93	95.25c	47.05a	5.31c	4.38b
Max	422.73	47.05	40.23	8.22
Min	3.51	23.28	1.31	4.38
Mean	183.14	34.21	17.23	5.77
SE±	48.50	2.78	4.75	0.35
LSD	20.73	1.86	2.36	0.29
Sig. levels	**	**	**	**

Legends: PbCS= Pb contaminated soil, UCS= Uncontaminated soil, ** = Significant at 1% level of probability. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

3.4. BCF Values for Pb Accumulation

BCF is a crucial parameter to evaluate the potentiality of a plant in accumulating metals and the values were calculated on dry weight basis. The bioconcentration factor of each plant variety was calculated separately against Pb concentration in contaminated and uncontaminated soils. Results presented in the Table 4, reflected that the BCF values of root varied significantly both contaminated and uncontaminated soils. The BCF values of shoots were comparatively higher in Pb contaminated soil than that of uncontaminated soil. The BCF values of root (2.09) and shoot (5.51) were highest in kenaf HC-95 for Pb contaminated soil indicating considerable bioaccumulation of Pb occurred. In uncontaminated soil, root BCF value (2.75) in jute CVE-3 and shoot BCF value (3.79) in kenaf HC-3 also indicates bioaccumulation of Pb form soils with lower Pb containing soil, the results suggesting that the higher or lower values of BCF for root or shoot of a plant did not depend upon the soil Pb content. BCF>1 indicates the plant is an "accumulator", <1 indicate the plant is an "excluder" (Baker, 1981). In the present study, both contaminated and uncontaminated soils, all the varieties were accumulator because all the BCFs values of roots and shoots were >1.

3.5. TF from Root to Shoot

The TF from root to shoot has been calculated to evaluate the mobilization of absorbed Pb from root to shoot. TF values were higher in Pb contaminated soil than uncontaminated soil. In contaminated soil, maximum TF (3.31) and minimum TF (1.02) were calculated form the variety of mesta Samu-93 and jute BJC-7370, respectively. On the other hand, in uncontaminated soil, maximum TF (1.96) and minimum TF (0.95) were calculated form the varieties of kenaf HC-3 and jute BJC-7370, respectively (Table 4).

Table 4. *BCF for root and shoot; and TF from root to shoot for jute, kenaf and mesta grown in Pb contaminated and uncontaminated soils.*

Plant variety	Bioconcentration Factor of Pb (BCF or BF) for root		Bioconcentration Factor (BCF or BF) of Pb for shoot		Translocation Factor (TF) of Pb from root to shoot	
	PbCS	UCS	PbCS	UCS	PbCS	UCS
Jute BJC-7370	1.27b	2.07b	1.29e	2.04e	1.02e	0.95e
Jute CVE-3	1.90ab	2.75a	2.40c	2.88d	1.27d	1.05d
Kenaf HC-95	2.09a	2.07b	5.51a	3.21c	2.65b	1.55c
Kenaf HC-3	1.77b	1.93c	4.08b	3.79a	2.30c	1.96a
Mesta Samu-93	1.09c	1.97c	3.60d	3.51b	3.31a	1.77b
Max.	2.09	2.75	5.51	3.79	3.31	1.96
Min.	1.09	1.93	1.29	2.04	1.02	0.95
Mean	1.62	2.16	3.38	3.09	2.11	1.46
SE±	0.11	0.08	0.39	0.16	0.23	0.11
LSD	0.124	0.074	0.066	0.088	0.166	0.047
Sig. levels	**	**	**	**	**	**

Legends: PbCS= Pb contaminated soil, UCS= Uncontaminated soil, ** = Significant at 1% level of probability. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

For all the studied varieties, the TF of Pb from root to shoot were slightly higher in Pb contaminated soil than uncontaminated soil and was agreed with the findings of Ramesh *et al*. (2010), they reported that the TF value of Pb was comparatively higher in Pb contaminated site than control when conducted experiment with 11 plant species in the soil of contaminated site and compared with control. TF < 1 indicates the slow translocation of an element. In the present study the TF > 1 indicated that the considerable amount of Pb accumulated in harvestable parts which was very much potential for phytoremediation. The current result supported by Islam *et al*., (2013) who found that arsenic and cadmium TF values for *Micranthemum umbrosum* ranges from 0.25 to 3.46.

3.6. Pb Contents of Post Harvest Soils and Recovery of Pb

To realize the remediation of the soil contaminated with Pb, the concentration of Pb in the pre planting and post harvest soil was also measured. After harvesting jute, kenaf and mesta the concentration of Pb in post harvest soils were less than the initial concentrations. The higher concentration of Pb in initial soil before planting, the more was the content in soil after harvesting. The recoveries of Pb were comparatively higher in uncontaminated soil than Pb contaminated soil. In case of contaminated soil, the highest concentration of Pb (108.12 mg Pb kg^{-1}) was detected from the post harvest soil cultivated with jute CVE-3 and the lowest (80.28 mg Pb kg^{-1}) was measured from the post harvest soil cultivated with kenaf HC-95. In this soil, maximum 80.39% and minimum 78.44% recovery were calculated from the soils cultivated with kenaf HC-95 and jute BJC-7370, respectively (Table 5).

In uncontaminated soil the highest (54.09 mg Pb kg^{-1}) and lowest (50.86 mg Pb kg^{-1}) concentration of Pb was detected from the post harvest soil cultivated with jute CVE-3 and mesta Samu-93, respectively (Table 5). In this soil, maximum 83.31% and minimum 70% recovery were also calculated from the soils grown with jute CVE-3 and jute BJC-7370, respectively (Table 5).The varieties of kenaf HC-3, kenaf HC-95, mesta samu, jute BJC-7370 and jute CVE-3 might have the enough potentiality to clean up Pb from the Pb contaminated soil. As a result, it can be said that the studied varieties have potentialities to remediate Pb form the contaminated soil.

Table 5. *Pb contents of post harvest soils and recovery of Pb after harvesting jute, kenaf and mesta.*

Plant variety	Pb CS			UCS		
	Pb contents of initial soil (mg kg $^{-1}$)	Pb contents of post harvest soil (mg kg^{-1})	Recovery of Pb (%)	Pb contents of initial soil (mg kg $^{-1}$)	Pb contents of post harvest soil (mg kg^{-1})	Recovery of Pb (%)
Jute BJC-7370	157.45	106.83ab	68.16c	69.74	51.85b	78.44c
Jute CVE-3	157.45	108.12a	69.81c	69.74	54.09a	83.31a
Kenaf HC-95	157.45	80.28c	80.39a	69.74	53.42a	80.74b
Kenaf HC-3	157.45	81.80c	78.34ab	69.74	50.58b	79.82bc
Mesta Samu-93	157.45	103.74b	72.26b	69.74	50.86b	80.31b
Max.	157.45	108.12	80.39	69.74	54.09	83.31
Min.	157.45	80.28	68.16	69.74	50.58	78.44
Mean	157.45	96.15	73.79	69.74	52.16	80.52
SE±	0.00	3.39	1.39	0.00	0.56	0.71
LSD	0.000	3.243	2.632	0.000	2.019	2.710
Sig. levels	NS	**	**	NS	**	**

Legend: PbCS= Pb contaminated soil, UCS= Uncontaminated soil, ** = Significant at 1% level of probability, NS = Not significant. In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

4. Conclusions

Pb contamination in soil is a problem since this harmful element entered into the biological system especially in human body and causing various kinds of diseases. In this circumstance the toxic element Pb should be remediate from the environment through eco-friendly phytoremediation approach. The major drawbacks of phytoremediation technology are the less biomass contents and post harvest materials treatment. The both of these drawbacks might be minimized by using these fibrous plants in case of Pb phytoremediation from soil as they have high biomass and post harvest materials could be used as biofuel, construction materials, paper pulp and firing/burning purposes. Therefore, the experimented varieties of jute, kenaf and mesta could be used for the phytoremediation of Pb from the contaminated soil.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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